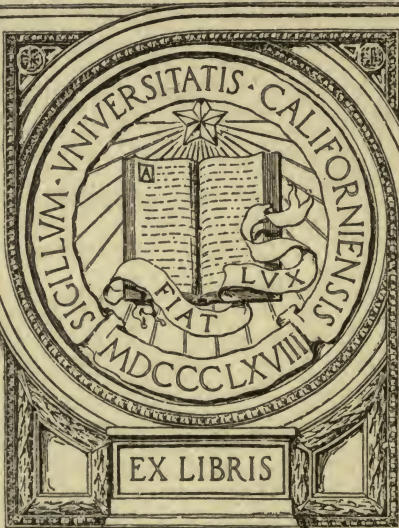


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LABORATORY DIRECTIONS

FOR BEGINNERS IN

BACTERIOLOGY

AN INTRODUCTION TO PRACTICAL BACTERIOLOGY
FOR STUDENTS AND PRACTITIONERS OF COM-
PARATIVE AND OF HUMAN MEDICINE

BY

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THIRD EDITION
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PREFACE TO THE THIRD EDITION

THE rapid advances that are constantly being made in bacteriological work demand frequent changes in directions for laboratory practice. The subject-matter contained in this elementary work has been readjusted to satisfy these requirements, a few exercises on new topics have been introduced, and the methods given have been modified to better meet the conditions of student laboratory work. Continued experience has strengthened our former opinion that a laboratory guide which outlines the work for each exercise and gives specific instructions for the same is of great assistance to both student and teacher. I desire to express my thanks and appreciation to Mr. G. Franklin White and Mr. Walter E. King for many valuable suggestions that have been incorporated in the recasting of these exercises.

V. A. M.

ITHACA, N.Y.

November, 1904

PREFACE TO THE SECOND EDITION

THE call for a second edition of these Laboratory Directions has come in such a short time that many of the difficulties encountered in the preparation of the first edition still remain. The choice of subject-matter and the selection of methods for a short elementary laboratory course become more and more difficult with the rapidly increasing developments in bacteriology. The recognized etiological importance of a number of bacteria which formerly were considered of little significance necessitates, for the best results, an extension of a knowledge of bacteriology beyond the differential characters and properties of a few pronounced pathogenic species.

Experience with the first edition has clearly demonstrated the advantage to both student and teacher of specific directions for a working basis in carrying out the various procedures in a laboratory course. The exercises have been considerably modified, four new ones added, and a few references appended for the purpose of aiding students in familiarizing themselves with the current literature on the subject.

In revising these exercises new text and reference books have been freely consulted. Valuable suggestions have also been received from a number of teachers and investigators. I am especially indebted for such assistance to Dr. Theobald Smith of Harvard University, Dr. Erwin F. Smith of the United

States Department of Agriculture, and to Mr. Raymond C. Reed and Mr. Floyd R. Wright, Instructors in the Department of Bacteriology in Cornell University. Suggestions and criticisms which may tend to increase the usefulness of these outlines are cordially invited.

V. A. M.

ITHACA, N.Y.

June, 1900

PREFACE TO THE FIRST EDITION

IT has been found desirable to provide the student, just beginning the study of bacteriology, with a somewhat detailed outline of the work to be done at each laboratory session. The selecting of the particular things to be done and the choosing of methods to be followed are difficult tasks. The assigning of directions for doing work under assumed conditions must necessarily partake of the empirical, and often fail. It is evident, however, that practical bacteriology must, if successfully taught, be cast in a somewhat definite form in order that the student may come to a knowledge of the fundamental principles underlying the subject in its twofold capacity, that of a pure science and of a useful art.

These outlines are intended either to serve simply as a guide through an introductory laboratory course preparatory to independent research work, or to form the basis for the application of the principles of bacteriology in the practice of human or of comparative medicine. They aim to impart a technical and working knowledge of certain of the more essential methods and to develop a definite knowledge of a few important species of bacteria. During the past year, they were furnished the students in mimeographed sheets, but after making the changes suggested by this application it seems desirable to put them in a more convenient form. In adjust-

ing the amount of work for each exercise to the necessary limitations of time and facilities, I am indebted to Mr. Raymond C. Reed, Instructor in this Department, for much valuable assistance. I wish also to thank Professor Charles Wright Dodge of the University of Rochester for helpful suggestions. Should these outlines fall in the hands of other teachers or workers in this subject, criticisms are cordially invited.

V. A. M.

ITHACA, N.Y.

August, 1898

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A LIST OF THE MORE IMPORTANT TEXT AND REFERENCE BOOKS

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Centralblatt für Bakteriologie, Parasitenkunde u. Infektionskrankheiten.

The Journal of Pathology and Bacteriology.

Zeitschrift für Hygiene u. Infektionskrankheiten.

Annales de l'Institut Pasteur.

Archives de Méd. Expérimentale et d'Anatomie Pathologique.

The Journal of Experimental Medicine.

The Journal of Medical Research.

The Journal of Infectious Diseases.

Annual Reports of the American Public Health Association.

All standard medical and veterinary journals.

Important articles on various topics in bacteriology frequently appear in journals on sanitary engineering, botany, chemistry, general biology, reports of city and state Boards of Health, United States Government Reports (especially those of the Bureau of Animal Industry and of the Marine Hospital Service), State Experiment Station Bulletins, and reports of scientific societies.

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APPARATUS AND MATERIAL

Apparatus. The apparatus and material for use in bacteriology in a student laboratory fall very naturally into three groups, viz. : (1) apparatus to be used in common by all students, and for which no individual is responsible excepting when in actual use by him, and the supplies from which each student draws the necessary quantity for the work assigned ; (2) apparatus to be assigned to each student for personal use and for which he is wholly responsible ; and (3) material such as notebooks to be provided by each. The assignment of equipment and supplies in accordance with this plan has been made in a general way, as indicated in the following paragraphs.

(1) **Apparatus in laboratory for general use.** This includes the apparatus and chemicals to be used in common by all students, and consists of pans and brushes for cleaning test tubes and other glassware, meat mincer and press, large and small water baths, steam sterilizers, hot-air sterilizers, incubators, thermometers, thermostats, gas burners, balances, leveling tripods, Wolffhügels' or other apparatus for aid in counting colonies, micrometers, metric rules, burettes, tripods, funnels, beakers, pipettes, graduates, glass tubing and rods, also the chemicals necessary for carrying on the work, such as various acids and alkalies, disinfectants, alcohol, aniline dyes, and those articles needed in the preparation of culture media, such as salt, peptone, agar, gelatin, meat extract, sugars, litmus and other

indicators, and filter paper ; fresh meat, eggs, milk, and potatoes being furnished as needed. The equipment also includes color charts and the more important books of reference.

(2) **Apparatus furnished for individual use.** The various appliances used by each student and for which he becomes personally responsible are a microscope with substage condenser, two oculars (1 and 2 inch) and three objectives ($\frac{2}{3}$, $\frac{1}{8}$, and $1\frac{1}{2}$ inch), a bottle of immersion oil, a hand magnifier, 75 small test tubes, 30 large test tubes, 10 fermentation tubes, 18 Petri dishes, 3 Erlenmeyer flasks, 7 one-ounce bottles for reagents and stains, supplied with pipettes or glass rods, 1 platinum-wire loop, 1 platinum-wire needle, 3 tin cups for holding cultures, 3 wire baskets for holding test tubes, 1 block for holding reagent bottles, 1 glass slide with ring attached for hanging-drop preparations, 1 tin tray for cover-glass preparations, 2 solid watch glasses, 2 ointment jars for used slides and cover glasses, and a glass box for clean cover glasses. Each working table is provided with a reserve-flame gas burner (Bunsen), glass jars for waste, and stands for holding culture tubes. Requisite amounts of absorbent cotton, lens paper, and towels are furnished when needed.

(3) **Material to be provided by each student.** A box of slides and cover glasses (cover glasses $\frac{3}{4}$ inch square preferred ; they must be between .12 and .18 mm. in thickness), a slide box for permanent preparations, gummed labels, preferably with name printed upon them, for slides and cultures, a Faber's blue pencil for marking on glass, fine forceps for handling cover glasses, and paper for laboratory notes with manila cardboard covers or suitable notebooks.

LABORATORY MAXIMS

1. See that the working table, instruments, and all pieces of apparatus used are thoroughly cleaned at the close of each exercise.

2. Unless otherwise directed, all cultures, other than those in gelatin, are to be grown in the incubator.

3. Gelatin cultures should not be put into the incubator except for special purposes not described in these directions.

4. In opening tubes of media or cultures always flame the open end of the tube immediately after withdrawing the plug. If the tubes have been standing for some time, the surface of the plug should be flamed before drawing it out. Never allow the tube end of the plug to touch, while out of the tube, any article by which it could become contaminated. It should be held by the top between the fingers.

5. In making transfers the tubes should be held as nearly in the horizontal position as possible. Cultures should not be opened in currents of air.

6. In every case where a platinum-wire loop or needle is used for making cultures or withdrawing media it should be carefully heated in a gas flame, or that of an alcohol lamp, both immediately before and after using. The heated wire must be allowed to cool before making cultures.

7. In making plate cultures work as much as possible under a hood and in still air.

8. If by accident, a drop or more of a culture should be spilled upon the table or floor, pour over it a sufficient quantity of a disinfectant (corrosive sublimate solution 1-1000, or a 5% solution of carbolic acid) to completely cover the infected area. After this has acted for ten minutes wipe it up and boil or burn the cotton or cloth. If any of the culture should drop on the hands or clothing, a disinfectant should be applied immediately.

9. In sterilizing culture media, always see that there is enough water in the pan of the steam sterilizer or in the water bath before lighting the gas. Do not put the media in a sterilizer and leave the laboratory.

10. Always disinfect, by boiling, all cultures before cleaning the tubes or plates containing them. (A liberal supply of cleaning mixture can be used to advantage in some instances for destroying cultures.)

11. At the beginning of each laboratory session read the directions for the next exercise in order to be able to make any preliminary preparations which may be required.

12. Careful notes should be taken on all observations made in the study of cultures and preparations made from them.

INTRODUCTION

Plan of exercises. Bacteriology has become one of the recognized branches in the curriculum of all medical and veterinary colleges. In many universities it is taught as a part of the course in general biology. It is, however, still a young science and the best methods for teaching it have not as yet been determined. All are agreed, however, that in addition to such text-book work and lectures as may be required there should be laboratory practice in actually handling and studying various bacteria and in determining their special morphological characters and physiological properties.

In order to differentiate the various species of bacteria, to isolate them from impure cultures or animal tissues, it is necessary that one should be familiar with the methods to be used; otherwise the attention will be directed more to the *modus operandi* than to the organisms themselves. On this point, however, there is much difference of opinion. Some laboratory workers believe that the methods should be taken up and learned in connection with the study of the various species of bacteria and thus avoid the loss of time that special instruction in methods requires. Others favor a devotion of a portion of the time to a consideration and drill in the methods to be employed later on in the course in the serious study of species and in diagnostic work.

The experience in this laboratory has been that the best results are obtained by teaching the more fundamental principles and methods as such before attempting to apply them in the study of the various species of bacteria or in practical diagnostic work. It has happened, even when the number of exercises is very limited, that a preliminary drill in the methods is greatly to the advantage of the student. From the nature of the subject, its application can be made and benefit derived therefrom only by those who know how to do the things that the exigencies of the moment demand. This means efficiency in knowing how. In following these directions, therefore, the student must understand that the purpose of the first twenty exercises is to teach him how to do the things called for in the later exercises in the study of species and in some of the practical applications of bacteriology.

Another feature of these directions is that they aim to teach the student how to study and observe bacteria in their cultures rather than to tell him what he is to observe. It is not intended that they should take the place of lectures and text-books in bacteriology. Their mission is to aid the student in finding out for himself what the text-books relate concerning certain species, and to guide him in the elementary steps in the more important diagnostic procedures, tests, and analyses.

The fact must also be recognized that in a short elementary course it is not possible to try several methods for doing the same thing. This restricts us to the use of a single procedure. The one is given that seems to us best adapted to the limited time and facilities of the student. It may happen, however, that other methods would be preferable under other

conditions or in the hands of certain individuals. This limitation is a necessity, however, in an elementary course of instruction. Its objection is partially met by references to text-books and other publications where other methods are described. It is very important that the student familiarize himself with at least a few of the more important books and periodicals dealing with bacteriology. They are the source to which he must go later for information on this subject, and consequently a knowledge of their nature and how to use them may be of unmeasured value.

LABORATORY BACTERIOLOGY

EXERCISE I

CLEANING GLASSWARE

1. It is necessary that the glassware employed should be thoroughly cleaned before it is used. Several special methods have been suggested for this purpose, but the one frequently employed by chemists seems to be the most easily handled and quite as efficient for general use as the more elaborate, specialized processes. It consists in applying the chromic acid cleaning mixture after washing the tubes and flasks with water. Experience has taught that usually this method may be abandoned, as a strong alkali is quite sufficient to clean the ordinary glassware. It is sometimes necessary to employ more special methods for cover glasses which are to be used in staining bacteria where a mordant is required. Only one of these special methods will be given here.

2. **Work for this exercise.** Clean all the glassware, test tubes, fermentation tubes, flasks, Petri dishes, and reagent bottles assigned.

If the next laboratory period occurs on the following day, place the flasks and test tubes in the incubator to insure their being dry before they are plugged.

Put the slides and cover glasses in the cleaning mixture; they can be rinsed and wiped later.

Read the laboratory maxims.

3. **Methods to be followed in cleaning the different apparatus.** (a) *Test tubes.* Wash the tubes carefully with a *strong* alkali soap and water, using the test-tube brush. Rinse the

tubes thoroughly in hot water and drain them, using a drainage board. [It is sometimes desirable to use the cleaning mixture.¹ In this case, after the tubes are washed with soap and water, they are stood in a glass jar (aquarium) and filled with the cleaning mixture. After it has acted for from 10 to 20 minutes, pour it back from the tubes into the bottle originally containing it. The tubes are then to be thoroughly rinsed and dried as before.]

(b) *Fermentation tubes.* Treat these with the cleaning mixture in the same manner as the test tubes. This is necessary because the brush cannot be used.

(c) *Flasks.* Wash the flasks thoroughly with soap and water. Then fill them with the cleaning mixture and allow it to act for at least 10 minutes, after which it is to be poured back. Rinse the flasks thoroughly in the same manner as the test tubes and drain them. When dry the outside should be wiped with a damp cloth.

(d) *Petri dishes and reagent bottles.* Thoroughly wash the Petri dishes and reagent bottles in hot soapsuds, after which rinse them separately in tap water and drain. The cleaning mixture need not be used. After they are dry the two parts of the Petri dish should be put together.

(e) *Cover glasses and slides.* Drop the cover glasses singly into a glass jar containing cleaning mixture and allow them to remain there for 24 hours or longer. Pour off the cleaning mixture and rinse the cover glasses in boiled water until all the color disappears; then cover them with alcohol until needed, when they can be wiped with a soft linen cloth or with lens

¹ *Formula for chromic acid cleaning mixture.* Dissolve 80 grams of potassium dichromate ($K_2Cr_2O_7$) in 300 cc. of warm water; when all of the $K_2Cr_2O_7$ is dissolved and the solution cooled, add it slowly, with constant stirring, to 460 cc. of concentrated sulphuric acid. Store the mixture in a glass-stoppered bottle. The liquid will be quite thick with small crystals. When the crystals are used up the liquid should be discarded.

paper. Sometimes there appears to be a film on the surface of the cover glasses which interferes in making hanging-drop preparations. Sometimes this can be overcome, after they are wiped out of the alcohol, by placing them in a Petri dish without the cover and heating them in the dry-air sterilizer at a temperature of 160° to 180° C. for one hour. After they have cooled, replace the cover and allow the cover glasses to remain in the Petri dish (a glass jar or other closed dish may be used) until used. (When a drop of water or bouillon is spread upon a properly cleansed cover glass it does not roll up in droplets, but will remain in a thin, even layer on the surface.)

Slides can be cleaned very satisfactorily by washing them in hot soapsuds, rinsing them in hot water, and wiping them with a soft cloth.

(f) *Cleaning used culture apparatus.* Place the tubes, flasks, or Petri dishes containing old cultures in a water bath, cover them with water, add a little sal soda (about an ounce to a gallon of water), and boil for 20 minutes. Pour off the water and empty the tubes, after which again boil them for 5 minutes in clean soap and water. Then wash and treat with the cleaning mixture the same as the new tubes. Cultures of spore-bearing pathogenic bacteria, such as those of anthrax, should be destroyed by heating in the autoclave at a temperature of at least 110° C. for half an hour before the tubes are emptied and washed.

4. A method for cleaning cover glasses for flagella stain. For this work the ordinary method of cleaning cover glasses is not sufficient, although the heating will often give a perfectly satisfactory cover glass. The following treatment was first highly recommended to me by Dr. Erwin F. Smith, and later modified by Johnston and Mack. First clean the cover glasses by the ordinary method, after which boil them in an agate cup or glass beaker in a 5% solution of caustic soda for 10 minutes. After cooling, rinse thoroughly in distilled water, place in a beaker, and cover with a 10% solution of hydrochloric acid

and boil for 10 minutes. Then pour off the acid and rinse the cover glasses, one at a time, using forceps for handling, in distilled water and finally in ether-alcohol. When needed, wipe with a piece of cheese cloth that has been properly prepared by soaking in a 5% solution of caustic soda for a few hours, then rinsed in water, and then placed for a few hours in dilute (10%) hydrochloric acid, after which it should be thoroughly rinsed in distilled water and dried. Before wiping the covers cleanse the hands thoroughly in soap and water, then in ether.

5. Laboratory notes. In this and all subsequent exercises careful notes should be taken on the work done. When, however, as in this exercise, it consists simply of carrying out directions, a simple statement that the work as directed was completely or partially done, as the case may be, is all that is necessary. In all other cases describe fully the work performed and observations made.

The notes should be as brief as completeness will permit. They should be legibly written and the technical terms peculiar to the subject in hand should be correctly used. The notes are to be handed to the instructor each week for examination and correction. When returned, all corrections should be carefully noted and similar errors should be avoided thereafter.

EXERCISE II

PLUGGING THE TUBES AND FLASKS AND STERILIZING
THE GLASSWARE

6. After the tubes and flasks are cleaned they must be plugged. The plugged tubes and flasks and the Petri dishes, all of which are to be used for holding culture media or in making cultures, must be sterilized before they can be used. The plugs should be neatly made and of the proper length and firmness. The best quality of absorbent cotton is ordinarily used for this purpose, although common cotton is employed in some laboratories. If the latter is used, it should be first heated to a very slight browning in the hot-air sterilizer. This drives off the oil and kills the spores which it might contain. Glassware is sterilized with dry steam or by means of dry heat, i.e. in the hot-air sterilizer. (See methods for sterilizing apparatus and instruments in text-books.)

7. **Work for this exercise.** Plug all the tubes and flasks with absorbent cotton and sterilize them, together with the Petri dishes.

After they are sterilized, store them in the locker until they are needed. The Petri dishes must not be opened until they are used.

If the periods are short this exercise and the following one may be worked together.

8. **Plugging the tubes and flasks.** For this purpose absorbent cotton is used. Rolls of it are cut in short segments of from 5 to 7 cm. in length. A piece of this narrow strip of sufficient length to give cotton enough for the plug is torn off. The quantity varies, of course, with the size of the mouth of the tube or flask, but a little experience will enable one to estimate the quantity quite accurately. The edges of the piece of cotton torn off are turned in and it

is rolled up to form a firm plug which should snugly fit the neck of the tube or flask. It should be inserted into the tube for about 2 cm. and the end should be nearly flat and smooth. The projecting part should be about the same length and of equal firmness. (For method of closing the tubes more securely, see § 22.)

9. Sterilizing glassware. (a) *Hot air.* Place all the test tubes, flasks, and Petri dishes in the hot-air sterilizer, close the door tightly, and light the gas. Heat the air in the sterilizer to a temperature of from 135° to 150° C. and keep it there for one hour, not allowing it to rise above 150° C. Turn the gas off, and when the temperature of the air in the sterilizer goes down to or below 45° C. the door may be opened and the apparatus removed.

(b) *Dry steam.* Sterilize the fermentation tubes in the autoclave at 15 lbs. pressure for half an hour. This method prevents a considerable amount of breakage, especially of the stand of the tube, that often occurs when these tubes are heated in the hot-air sterilizer.

EXERCISE III

THE PREPARATION OF BOUILLON

10. Bouillon is the liquid medium most commonly employed in cultivating bacteria. It is practically a beef tea containing peptone. There are several methods recommended for making it. It may be made directly from simple meat infusion or it may be made from meat extract. The meat infusion is prepared either by allowing finely chopped lean meat mixed with twice its quantity of distilled or filtered and boiled tap water (2 cc. of water for each gram of meat) to stand in a cool place for from 12 to 18 hours, or the mixture of meat and water may be heated with frequent stirring at a temperature of 65° C. for a short time (one hour). Each has its advantages. When meat extract is used in place of the meat infusion, the bouillon does not seem to be a favorable culture fluid for certain bacteria. In making bouillon, therefore, it becomes necessary to determine the kind (whether from meat infusion or extract) and the method of preparing it to suit the conditions in hand. It is sometimes desirable in bacteriologic investigations to resort to all of these methods. For routine work in the laboratory, bouillon prepared directly from the meat by macerating it for a short time at a high temperature (60° to 65° C.) is very satisfactory. The addition of peptone and the neutralization of the liquid are the same in both cases.

Bouillon is used as the nutritive base in preparing agar and gelatin. On this account large quantities are stored in flasks. (For other methods see text-books. Also Report (Journal) of the Am. Public Health Asso., January, 1898, p. 77.)

REFERENCES. Chapters on making culture media in text-books. Jour. of the Am. Public Health Asso., October, 1895, and January, 1898, p. 77. Smith, The Jour. of Exper. Med., Vol. III (1898), p. 647.

11. Work for this exercise. Make 1000 cc. of bouillon and distribute it as follows :

Put 5 cc. in each of 10 small sterile test tubes.

Put 300 cc. in each of 2 large (500 cc.) Erlenmeyer flasks, and the remainder in a third flask.

Put 5 cc. of distilled water in each of 5 small sterile test tubes and sterilize them with the bouillon. (They are to be used subsequently in place of bouillon in making dilutions.) Label the tubes "sterile distilled water." All media required to carry out the directions will be furnished by the instructor excepting such as the student is directed to make in Exercises III, IV, and X.

12. The preparation of bouillon. Take 500 grams of lean beef, remove all fat, and grind it in a sausage machine or have it minced at the butcher shop. Place the minced meat in an agate-iron dish, add 1000 cc. (2 parts water to one of meat) of clear boiled water, cooled to 65° C., and stir thoroughly with a glass rod. Then macerate it, with frequent stirring, in a water bath at a temperature of 60° C. for one hour after the temperature of the meat and water reaches that of the water outside or, to save time, at a temperature of 65° C. for 30 minutes. Remove the meat by straining the liquid through a piece of cheese cloth. For this a stout iron meat press is desirable. Boil the strained meat infusion for 20 minutes.¹ Cool to harden the fat, and filter through filter paper. The filtrate should equal in quantity the amount of water used ; if it does not, add enough distilled or clear boiled water to make up that amount. To this meat infusion add 1% peptone (Witte's) and $\frac{1}{2}$ % sodium chloride. Add enough of a normal solution of sodium hydrate to give the liquid a faintly alkaline reaction when litmus is used as an indicator. (For method of titrating media, see § 14.) The infusion is then boiled in a water bath

¹ In case of a short period, the exercise may be divided at this point by boiling the infusion for 30 minutes and keeping it overnight. The receptacle should be covered.

for three quarters of an hour and filtered hot. The filtrate should be perfectly clear. The color will vary according to the amount of blood pigment in the meat used, and according to the length of time it is steamed or boiled, i.e. according to the amount of material precipitated out. After filtering, distribute the bouillon in tubes and flasks (see above), and stand them in a wire basket for sterilization. Sterilize them by boiling in a closed water bath or steaming in the Arnold's steam sterilizer for 30 minutes,¹ the time to be computed from the time the water boils or the temperature in the steamer reaches 99°. The flasks of bouillon should be boiled or steamed for 20 minutes on each of the two succeeding days (certain anaërobic bacteria may not be destroyed by this treatment). When they have cooled the outside of the tubes should be carefully wiped with a moist cloth and placed in the incubator until the next laboratory day. Then carefully examine them, and if any of the tubes are contaminated, that is, if the liquid is clouded or has a membrane on the surface, they must be rejected. Label the others and place them in the locker.

¹ The customary method of sterilizing culture media is to steam or boil them for about 10 minutes on each of 3 consecutive days. This was found very troublesome by the students, and, feeling that it was not necessary, a long series of test experiments was made by Mr. R. C. Reed, who found that 1 boiling or steaming for 30 minutes gave just as good results as the customary 3 boilings. As the media are not used for 2 or 3 days after sterilization, during which time they are kept in an incubator, the method is well suited to student laboratories, not for the reason that it saves time in preparing the media, but it relieves the congestion in the sterilizer and appreciably aids the student. *When sterilized by this method the media must not be inoculated for several days after their preparation or until they have stood in an incubator for at least 18 hours to test their sterility.*

Media can be quickly sterilized by means of the autoclave when the temperature is raised from 110° to 115° C. While this method is quick and convenient, the high temperature seems to be detrimental to media for certain pathogenic bacteria. The autoclave, however, is quite extensively used.

13. Labeling media and culture tubes. Stick on each tube of medium, about 3 cm. from the top, an adhesive white label about 2 cm. square. On the upper line should be written the name of the medium and the date of its preparation. Thus, "bouillon, 13-VII-1900." When the tube is used the name of the organism or material with which it is inoculated, together with the date of inoculation, should be written on the lower lines. This applies to all media and tube or flask cultures.

14. Titration of bouillon. Take 5 cc. of bouillon and place in a porcelain evaporating dish with about 45 cc. of water. Boil for three minutes. Add 1 cc. of a solution of phenol-phthalein. Stir and add to the solution in the evaporating dish enough of a N/20 NaOH solution from a burette to give it a clear, bright pink color. This amount then of N/20 NaOH solution is required to neutralize 5 cc. of the bouillon. A provisional standard reaction of +1.5 to phenol-phthalein has been adopted. This would be slightly alkaline to litmus. In order to bring the entire amount of bouillon to the desired reaction (+1.5), subtract 1.5 from the amount of N/20 NaOH solution drawn from the burette and multiply the difference by the number of cc. of bouillon divided by 100. The product, if plus, represents the amount of N/1 NaOH to be added; if minus, the amount of N/1 HCL to be added. After mixing, test the reaction again in the same way and add alkali or acid if needed. For greater accuracy further tests should be made. (For a more complete discussion of the reaction of culture media, see Appendix I.)

EXERCISE IV

THE PREPARATION OF GELATIN AND AGAR

15. Of the solid media employed in cultivating bacteria, agar and gelatin are most commonly used. They depend for their nutritive properties largely upon the bouillon from which they are made, the agar and gelatin forming simply the solidifying elements. The striking difference between the two is that the gelatin melts at the body temperature, whereas the agar is not quickly liquefied below the boiling point. For this reason gelatin is not used as a solid medium for cultivating bacteria at a high (body) temperature. There are several processes for preparing these media, but the addition of the dry agar and gelatin to bouillon (§ 12) either immediately after it is filtered or later after it has been sterilized and stored in flasks seems to be the most convenient procedure. The agar itself is usually neutral in reaction, but the gelatin often has a decidedly acid reaction. This necessitates the careful testing of the reaction of the two media, although the bouillon is neutral or slightly alkaline.

REFERENCES. Chapters on culture media in text-books on bacteriology. The preparation of nutritive agar, *American Microscopic Journal*, May, 1890. A rapid method of making agar-agar, *Johns Hopkins Hospital Bulletin*, No. 24, July-August, 1892. *Jour. of the Am. Public Health Asso.*, January, 1898.

16. **Work for this exercise.** See that bouillon made in Exercise III is properly sterilized. Prepare 300 cc. of gelatin and 300 cc. of agar, i.e. start with 300 cc. of bouillon for each. There will be considerable shrinkage owing to the amount lost on the dishes, filter, etc., so that the quantities of media will be appreciably less than this amount. Distribute each medium as follows :

Put 5 cc. in each of 10 small sterile test tubes.

Put 10 cc. in each of 12 large sterile test tubes.

Put the remainder in the flask which contained the bouillon.

17. The preparation of nutrient gelatin. Take a flask of bouillon containing 300 cc. and pour it into a small agate iron dish, add 30 grams of sheet gelatin, and heat, with frequent stirring, in a water bath, until the gelatin is dissolved. Allow it to cool to a temperature between 45° and 50° C. and then add the white of one egg and mix it thoroughly by stirring, or, better, by pouring the gelatin many times from one flask or beaker to another. After the egg albumen is completely diffused, return the liquid gelatin to the large covered water bath and boil until the egg albumen is firmly coagulated. This takes about 20 minutes. It is now ready for filtering, which must be done while the gelatin is hot. Filter through properly folded¹ but ordinary filter paper, first moistened with boiling water. Distribute the filtrate as directed. In pouring the gelatin into the tube use a small beaker or graduate, and see that the gelatin does not touch the sides of the upper part of the tube. Stand the tubes in a wire basket and sterilize them by boiling in a closed water bath or by steaming in the Arnold steam sterilizer for 30 minutes. The small flasks can be sterilized in the same manner. Place tubes and small flasks in the incubator and allow them to remain there for two days. If the gelatin in any of the tubes becomes cloudy, the medium in those tubes must be rejected. Carefully wipe all the other tubes with a moist cloth, label, and place them in the locker, where they can be kept until used.

18. The preparation of nutrient agar. Weigh out 3 grams of agar and cut it into small pieces with a pair of scissors. Put the finely cut agar into an agate-iron dish, add 75 cc. of distilled water, and boil over a gas flame, with constant

¹ For illustrations and directions for folding filter paper, see Abbott's *Principles of Bacteriology*, 6th edition, p. 101. Filter paper already folded may be procured.

stirring to prevent scorching, until the agar is dissolved, giving a thick, homogeneous, pasty substance. Pour 300 cc. of bouillon (§ 11) from a flask into the cup containing the dissolved agar. Place the dish containing the mixed agar and bouillon in a closed water bath and boil for 20 minutes, then cool it to a temperature between 45° and 50° C., add the white of one egg, and thoroughly mix in the liquid agar. This is easily accomplished by pouring it a number of times from one beaker to another. When the egg albumen is dissolved the agar is returned to the water bath and boiled vigorously until the white of the egg is firmly coagulated. This usually takes about 20 minutes. Filter the agar immediately, while hot, through ordinary filter paper which has been moistened with boiling water. Distribute the filtrate in small and large tubes, as directed. Sterilize, label, and store the agar in the same manner as the gelatin.

EXERCISE V

INOCULATING TUBES OF BOUILLON, AGAR, AND GELATIN

19. Work for this exercise. See that the media made in former exercises have been properly sterilized. Inoculate one tube of bouillon, two (one inclined, the other not) of agar, and one of gelatin from a culture of *Bacillus coli communis*, which will be furnished.

Wipe the slides. Transfer the cover glasses from the cleaning mixture to water and then to alcohol. Seal the agar slant and gelatin tubes.

Read the chapters in one or more text-books on inoculating media or making tube cultures.

20. Inoculating bouillon. In making this culture, carefully remove the plug from the tube of bouillon by first twisting it around to detach any adhesions and then by pulling it straight out. Pass the open end of the tilted tube quickly through the gas flame. The plug, which has meantime been carefully held, is partially replaced and the tube returned to its stand. Treat the tube containing the culture (which has been furnished) in the same manner. Then place the two tubes side by side between the thumb and forefinger of the left hand, palm facing upward, and grasp them about the middle of the upper half (see Fig. 38, p. 108, Crookshank). Sterilize the platinum loop by passing it through the gas flame, care being taken that the handle is also flamed for a distance of at least 15 cm. Then carefully remove the plugs from the tubes and hold them between the fingers in such a manner that the tube ends, projecting outward, will not touch anything during the inoculation process. Insert the wire loop carefully into the culture and transfer a loopful of the culture to the tube of bouillon and gently rinse it from the loop. The loop is then withdrawn, the

plugs replaced in their respective tubes, and the loop flamed and put aside. Label the freshly inoculated tube with the name of the organism, source, and date. Stand it in a tray or cup and place it in the incubator.¹ This should be kept at a temperature between 35° and 37° C. The organism thus transferred should multiply so that on the following day the liquid will be cloudy. It is then a bouillon culture of *B. coli communis*.

21. Inoculating tubes of agar. *Ordinarily the agar is inclined before it is inoculated.* In this case it is spoken of as inclined or slant agar. Occasionally the agar is inoculated without inclining it. Cultures made in this manner are spoken of as "stab" or "stick" cultures. (a) *Inclined or slant agar.* Stand a tube of agar in a wire basket in a water bath and boil it until the agar is liquefied. (To save repeating this it is well to incline the agar in several tubes which can be kept for future use, but after the slants have been made for a long time it is better to boil and reslant them, especially if they are to be used for organisms which do not grow well on a dry surface.) Lay the tube on a tray, the top resting on the side of the tray so that the surface of the agar will be about 4 cm. long, and allow it to cool. In placing the tubes the label should be up. When the agar has set it is ready for use. It is inoculated precisely as the bouillon, excepting that the loopful of culture is drawn over the inclined surface instead of being thrust into the medium as in the bouillon. Label and place it in the incubator with the inoculated bouillon tube. On the following day there should be a grayish-white growth

¹ For illustrations and descriptions of different kinds of incubators, see text-books. It is desirable to note especially the various burners and thermoregulators employed to heat and regulate the temperature of the incubators. Considerable information may also be acquired by carefully looking through the catalogues of manufacturers and dealers in bacteriologic apparatus. Copies of some of these will be found on the reference bookshelves.

on the surface of the agar covered by the loop. This is an agar culture of *B. coli communis*. (b) *Stick cultures*. These are made with a platinum needle in the uninclined agar. The impregnated needle is pushed down through the center of the agar. In all other respects this culture is made like the slant-agar culture.

22. Inoculating tubes of gelatin. Tube cultures in gelatin are usually made without inclining the gelatin, i.e. stick cultures. The tube of gelatin is inoculated in the same manner as the stick culture in agar. This tube is to be placed in the locker, as the gelatin will melt at the incubator temperature. The growth will appear along the needle track in about two days. This is a gelatin culture of *B. coli communis*.

23. Sealing culture tubes. It is often desirable to seal cultures to prevent their drying out quickly. A convenient method, and one which has long been in use in some laboratories, is to boil a small quantity of paraffin in a small agate-iron dish and while it is still hot carefully dip the tube end of the plug into it and quickly replace it in the tube. The paraffin on cooling fills the spaces between the fibers of cotton and also adheres to the sides of the tube, forming a tight plug. When the tube is to be opened the end must be warmed slightly before the plug can be withdrawn. The plugs should be paraffined and the sterility of the tubes determined before they are used for cultures.

EXERCISE VI

THE EXAMINATION OF CULTURES

24. In studying cultures of bacteria it is necessary to observe very carefully (1) the macroscopic appearance of the growth in or upon the media, (2) the microscopic appearance of the bacteria in (a) the living condition (hanging-drop preparation) and (b) in the dead and stained condition (cover-glass preparation), and (3) the effect of the growth of the bacteria upon the chemical and physical properties of the medium. To determine these the cultures must be kept under observation for several days and often for several weeks. A careful record should be made of the changes observed in the appearance of the cultures. Illustrate with drawings.

25. Work for this exercise. Examine carefully and describe fully the appearance of the bouillon, agar, and gelatin cultures made in Exercise V.

Determine the reaction of the bouillon culture and note whether there is any change in its consistence (viscosity).

Make a hanging-drop preparation from each culture and examine and describe the appearance of the bacteria in each.

Make a drawing of the gelatin and slant-agar cultures and also of a few of the bacteria in one of the hanging-drop preparations.

Read the paragraphs in one or more text-books on the examination of cultures and hanging-drop preparations.

26. Suggestions for the macroscopic examination of cultures. The external appearance of cultures should be observed and noted on the day after they are made and on each succeeding day until the growth ceases. In bouillon cultures note the appearance of the liquid, whether uniformly, faintly, or heavily clouded, turbid, clear, or clouded with flocculent masses held

in suspension, the quantity and nature of sediment, and the presence or absence of a membrane. The reaction of the liquid should be taken and its consistence noted. The odor should be determined. In agar cultures the extent of the growth (feeble, moderate, or vigorous), its color, form, and surface appearance (dull or glistening), should be observed. The character of the growth in the condensation water should also be noted. In stab cultures the appearance of the growth both on the surface and along the needle track should be described. In gelatin the absence or the presence and extent of liquefaction should be noted in addition to the features already referred to for the stab-agar cultures. (See Chester's terminology, §§ 31 and 51.)

27. Testing the reaction of liquid cultures. Place a small piece of each of the red and blue litmus papers in a solid watch glass. With the platinum loop carefully place a drop of the culture on each piece of the paper. After recording the reaction produced, — neutral, acid, or alkaline, with the degree, — cover the paper with a disinfectant (a solution of corrosive sublimate 1 to 1000). After it has acted for about 10 minutes, empty it with the paper into the waste jar and wash the watch glass.

28. To determine the viscosity. (a) *Bouillon cultures.* Insert the platinum loop into the liquid and carefully withdraw it. The approximate degree of viscosity may be determined by the extent of the adhesion of the liquid to the loop and by the length of the threadlike filament drawn out. By gently shaking the tube, a viscid sediment will rise up, appearing as a somewhat twisted, tenacious cone with its apex reaching to or near the surface. A friable sediment will break up and become disseminated through the liquid upon agitation. (b) *Agar and gelatin cultures.* Touch the surface growth with the end of the platinum needle, and if it is viscid, a threadlike string will be drawn out. Note whether the growth is pasty or friable.

29. Making hanging-drop preparations. (a) *From a bouillon culture.* Place a clean cover glass on a tray. With the loop remove a drop of the liquid culture and place it on the middle of the cover glass. With a pair of fine forceps invert the cover glass over the glass ring fixed to a slide for this purpose. The surface of the ring should previously be moistened with liquid vaseline to prevent the cover glass from sliding. The preparation is then ready for examination. Examine it first with the high-power dry lens and then with the oil-immersion objective. (For directions on the use of the microscope, see *The Microscope*, by Professor S. H. Gage.) (b) *From cultures on solid media.* On account of the very large number of bacteria in the growth on solid media it is necessary to separate them in a clear liquid. Take a cover glass as before and place a loopful of bouillon or sterilized water on the center. Touch the surface growth very gently with the end of the platinum needle and carefully rinse it in the drop of liquid on the cover glass. From this point the examination is the same as with the liquid culture. Upon examination, if the bacteria are so numerous that the individual organisms cannot be clearly distinguished, i.e. separated from each other, the preparation must be rejected and another one made, using a smaller quantity of the growth. After examination the cover glasses should be placed at once in a glass jar containing a strong disinfectant (5% carbolic acid, 1 to 1000 corrosive sublimate solution, or a strong solution of a mineral acid).

30. Suggestions for the microscopic examination of living bacteria. In examining the bacteria as they appear under the microscope in the hanging-drop preparation the following features should be observed: Are the individual bacteria spherical, rod-shaped, or spiral in form? Are they single or united in pairs, masses, or clumps, or in shorter or longer chains? For this determination it is better to examine the organisms near the edge of the drop. Are they motile, that is,

do the individual bacteria move from one point in the field to another? To determine this the center of the drop is better. Clearly distinguish between genuine motility and a simple dancing motion (the Brownian movement). Determine the presence or absence of spores. These are bright, highly refractive bodies either within or outside the bodies of the bacteria. If present, they can usually be seen in both positions. Is there any evidence of a capsule around the bacteria?

31. Chester's terminology for descriptive bacteriology. Chester has introduced a terminology in descriptive bacteriology which has the advantage of being definite and concise, while at the same time it is sufficiently elastic to fit the varying

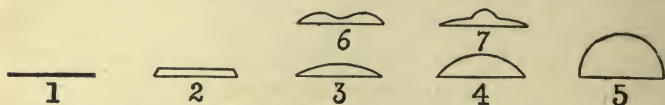


FIG. 1. Characters of surface elevation: 1, flat; 2, raised; 3, convex; 4, pulvinate; 5, capitate; 6, umbilicate; 7, umbonate.

forms of growth. It applies to the surface growth, to the growth along the needle track in the depth of the media, and to colonies on plate cultures.

1. Surface elevation. General character of surface growth as a whole.

Flat: thin, leafy, spreading over the surface.

Effused: spread over the surface as a thin, veilly layer, more delicate than the preceding.

Raised: growth thick, with abrupt terraced edges.

Convex: surface the segment of a circle, but very flatly convex.

Pulvinate: surface the segment of a circle, but decidedly convex.

Capitate: surface hemispherical.

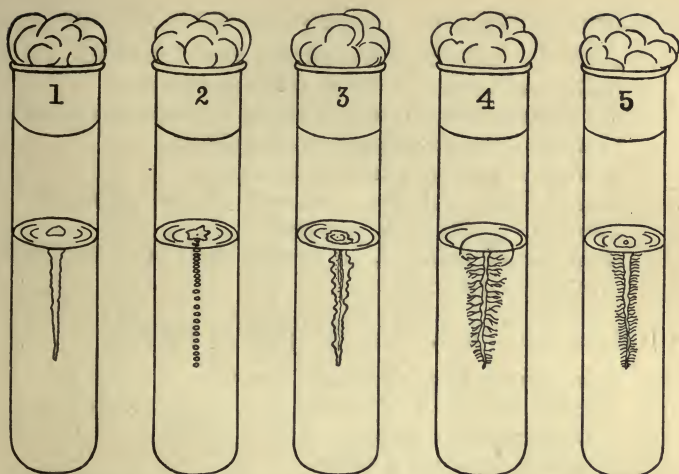


FIG. 2. Characters of growth in depth of media: 1, filiform; 2, beaded; 3, tuberculate-echinulate; 4, arborescent; 5, villous.

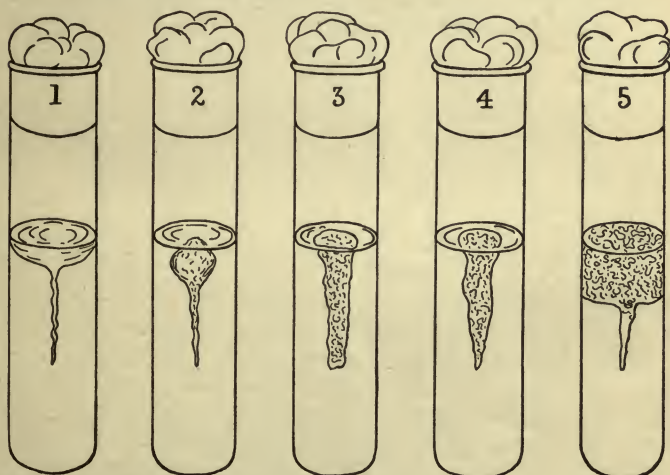


FIG. 3. Types of liquefaction in gelatin stab cultures: 1, crateriform; 2, napiform; 3, saccate; 4, infundibuliform; 5, stratiform.

2. Gelatin stab cultures. Nonliquefying line of puncture.

Filiform: uniform growth, without special character.

Nodose: consisting of closely aggregated colonies.

Beaded: consisting of loosely placed or disjointed colonies.

Papillate: beset with papillate extensions.

Echinate: beset with acicular extensions.

Villous: beset with short, undivided, hairlike extensions.

Plumose: a delicate feathery growth.

Arborescent: branched, or treelike, beset with branched hairlike extensions.

3. Gelatin stab culture. Liquefying line of puncture.

Crateriform: a saucer-shaped liquefaction of the gelatin.

Saccate: shape of an elongated sack, tubular, cylindrical.

Infundibuliform: shape of a funnel, conical.

Napiform: shape of a turnip.

Fusiform: outline of a parsnip, narrow at either end, broadest below the surface.

Stratiform: liquefaction extending to the walls of the tube and downward horizontally.

EXERCISE VII

MAKING AND STAINING COVER-GLASS PREPARATIONS,
AND FORMULÆ FOR STAINING SOLUTIONS

32. Work for this exercise. Make 2 cover-glass preparations from each of the cultures made in Exercise V and stain one of each with alkaline methylene blue and the other with carbol fuchsin. Describe the appearance of the bacteria and make a drawing of a few individual bacteria from the preparations made from the agar culture.

Preserve a cover-glass preparation mounted in balsam and labeled to accompany notes.

Prepare the staining fluids used in this exercise from the formulæ given (§ 37).

Read the paragraphs in the text-books on making and staining cover-glass preparations. See references and text-books for various staining solutions that are sometimes used.

33. Making cover-glass preparations. (*a*) *From bouillon cultures.* Place two clean cover glasses on the tray. With the loop remove a drop of the bouillon culture and spread it in a thin layer over about two thirds of the surface of the cover glasses. One loopful will ordinarily make from 2 to 4 preparations. Allow the liquid to dry on the cover glasses in the air and, when dry, fix the bacteria to them by passing them, film upward, three times through the middle of the upper half of the gas flame. Each passage (complete circle) should not occupy more than one second. After fixing they are ready for staining. (*b*) *From cultures on solid media (agar, gelatin, potato, serum, etc.).* Place the cover glasses on the tray, and on the center of each put a drop of sterile water or bouillon. Touch the surface growth of the culture with the end of the needle and then gently rinse it in the liquid on the covers. Spread the liquid on the covers as before. From

this point the procedure is the same as that for the preparations made from the bouillon culture.

34. Staining bacteria in cover-glass preparations. (a) *With alkaline methylene blue.* With the pipette place a few drops of the staining solution on the film side of the fixed preparation, which is either held horizontally with the fine forceps or left resting on the tray. Allow the stain to act for 2 or 3 minutes; then carefully rinse it off in water, holding the cover firmly by one edge with the forceps. After thoroughly rinsing, place the preparation, film downward, on a clean slide and dry the upper surface with a piece of filter paper. It is now ready for the microscopic examination. Use first the dry lens ($\frac{1}{8}$ -in. obj.) and then the oil-immersion objective. If the specimen is a good one and it is desirable to preserve it, wipe off the drop of oil with a piece of lens paper and run a drop of distilled water under the cover glass, which will float it, when it can be easily removed with the forceps. Place it on the tray, film upward, and when dry, mount it in a neutral or slightly alkaline Canada balsam.¹

(b) *With carbol fuchsin.* Moisten the film side of the cover glass with water (using the pipette); then cover it with the stain and allow it to act for from 10 to 30 seconds. Then rinse it thoroughly in water, after which cover it with $\frac{1}{10}$ % solution of acetic acid or strong (95%) alcohol. Allow this to act for from 5 to 10 seconds, and again thoroughly rinse in water and examine as above. (For other decolorizers, see text-books.)

Upon examination the preparation should be free from deposits or stained background. The bacteria should, as a rule, be isolated and distinct; unless they are the preparations are not satisfactory.

¹ To neutralize balsam, add some pure sodium carbonate to it and allow it to stand for about a month in a warm place, shaking it from time to time. Then allow the sodium to settle. The clear supernatant balsam will be found to be slightly alkaline.

Cover-glass preparations of bacteria are permanently mounted in the same manner as similar preparations made from the blood or other tissues in histology, the process being to put a drop of balsam on the center of the slide and place the preparation, film downward, over it and apply slight pressure. Label the preparation, giving the name of the organism, its source (kind of culture, tissue, etc., from which the preparation was made), stain used, and date. If the specimen is not preserved, the slide and cover glass should be cleaned for future use.

35. Suggestions concerning the microscopic examination of stained preparations of bacteria. In the examination of the bacteria in the stained condition the following points, and perhaps others, should be observed and noted. (a) *Concerning their morphology.* Are they spherical, rod-shaped, or spiral? Are they separated or united in clumps or chains? If rod-shaped, are the ends pointed, round, or square? Are the bacteria all of the same form and size? Note the presence or absence of spores, granules, and capsules. (b) *Concerning their reaction to staining fluids.* Do they stain uniformly or irregularly? Do they stain deeply or faintly? Is the center lighter than the periphery? Are there an unstained central band and deeply stained ends (polar stain)? Do all of the bacteria take the stain alike?

36. Staining solutions. The basic aniline dyes are used in staining bacteria. There is a large number of these, and there are several formulæ for preparing staining solutions from each. Further, as will be seen from the chapters on staining bacteria in the text-books, there are several methods of applying these stains. In an introductory course, however, it is impossible to try them all, and consequently only those are described which seem to be the best adapted for general use.

In addition to the ordinary staining solutions and methods there are special processes for certain species, such, for example, as the tubercle bacterium, and still others for staining certain parts of many bacteria, such as the flagella on motile

forms, the spores in spore-bearing organisms, and the capsule on certain other species. There is a large number of these special methods, but in this course only one of each will be given. These will be taken up in connection with the study of the bacteria requiring them.

37. Formulæ for staining solutions. The dyes here used are methylene blue, gentian violet, methyl violet, and basic fuchsin. For the other dyes, see text-books.

ALKALINE METHYLENE BLUE (LOEFFLER)

Saturated alcoholic solution of methylene blue .	6 cc.
Caustic potash (1 % solution)	0.2 cc.
Distilled water	20 cc.

The saturated alcoholic solution of the methylene blue (or of any of the dyes) is prepared by pouring the dye into a clean bottle and filling it about one fourth full. Then fill the bottle with strong (95 % or absolute) alcohol, cork tightly, shake, and allow it to stand for 24 hours. If at the end of that time the dye is entirely dissolved, add more, shake thoroughly, and allow it to stand for another day. Repeat this procedure until there is a permanent sediment of undissolved coloring matter in the bottom of the bottle. Then label. (The saturated solution will be kept in stock in the laboratory.)

CARBOL FUCHSIN (ZIEHL'S SOLUTION)

Fuchsin (dry)	1 gram
Alcohol (absolute)	10 cc.
Carbolic acid (5 % solution)	100 cc.

Dissolve the fuchsin in the alcohol, after which add the carbolic acid solution. Instead of using the dry fuchsin and alcohol, 11 cc. of a saturated alcoholic solution of fuchsin may be used.

It is more convenient for each student to prepare the following : —

Saturated alcoholic solution of fuchsin	3 cc.
Carbolic acid (5 % solution)	20 cc.

If the mixture is not clear, add more of the saturated alcoholic solution of fuchsin drop by drop until when viewed through the pipette by transmitted light the liquid is perfectly clear.

ANILINE GENTIAN VIOLET (EHRlich-WEIGERT)

Saturated alcoholic solution of gentian violet	11 cc.
Absolute alcohol	10 cc.
Aniline water	100 cc.

It is more convenient for each student to prepare one fifth of this quantity.

CARBOLIC THIONINE BLUE (NICOLLÉ)

Thionine blue	1 gram
Carbolic acid	2.5 grams
Distilled water	100 cc.

Filter. Before using, dilute with an equal quantity of distilled water and filter again.

CARBOLIC GENTIAN VIOLET (NICOLLÉ)

Gentian violet (saturated alcoholic solution)	10 cc.
Carbolic acid (1 % solution)	100 cc.

Mix and filter before storing.

38. Aqueous solutions. Aqueous solutions of methyl violet, gentian violet, fuchsin, and the other aniline dyes are prepared by adding 1 cc. of the saturated alcoholic solution of the desired dye to 20 cc. of distilled water. This will impart a decided color to the liquid, so that in a pipette it will be barely transparent.

The true aqueous solutions are made by dissolving the dyes in water, but these are weak and not so effective as those prepared from the alcoholic solutions. These solutions deteriorate in a short time. The carbol fuchsin and alkaline methylene blue will keep a little longer, but they require filtering occasionally.

39. Making aniline water. Aniline water is a saturated aqueous solution of aniline oil. It is prepared by adding 1 cc. of aniline oil to 20 cc. of distilled water and shaking frequently for from 15 to 30 minutes. It is convenient to use a stoppered vial or large test tube for mixing it. Filter through a moistened filter paper. The filtrate should be perfectly clear. If it is cloudy, it should be refiltered before using. This is used in preparing the aniline water dyes, such as methyl violet, gentian violet, etc.

40. Gram's method of staining bacteria. Prepare the cover-glass preparations as already described. Stain them in gentian-violet aniline water, or in a saturated alcoholic solution of gentian violet in 5 % carbolic acid in the proportion of 1 to 20 for from 5 to 7 minutes. Rinse in water and transfer them to a watch glass containing Gram's solution until the color becomes quite black. This requires from 1 to 2 minutes; then place the preparations in a watch glass containing alcohol and allow them to remain there until the color has almost entirely disappeared, or has become a pale gray. Rinse in water and examine at once, or allow them to dry and mount in balsam. (Sections of tissues must be dehydrated and cleared before mounting.)

GRAM'S SOLUTION (LUGOL'S)

Iodine	1 gram
Potassium iodide	2 grams
Distilled water	300 cc.

Certain bacteria stain deeply and retain the coloring matter when treated by this method, while others are decolorized by the alcohol. On this account some investigators consider it an important aid in the differentiation of certain bacteria.

EXERCISE VIII

MAKING PLATE AND ESMARCH ROLL CULTURES

41. The general principle underlying the separation of bacteria by means of plate and roll cultures is to dilute the substance containing the bacteria so that the individual organisms will be separated from each other by an appreciable distance and then fixed in a solid medium where each organism can multiply into a growth or colony without coming in contact with any other organism or colony. For this purpose agar and gelatin are used. Originally Koch employed a rectangular piece of glass for holding the layer of medium, and protected it from contamination by putting it under a bell jar. Later Esmarch introduced the "roll-culture" method, which was extensively followed until the Petri dishes were introduced. Since that time the latter have been largely used in place of the Koch plate and Esmarch tube. On this account the plate cultures of to-day are usually made in Petri dishes. The roll culture is also used.

Plate cultures are employed for two distinct purposes: (1) to isolate bacteria in order to obtain pure cultures from the isolated colonies; and (2) to determine how many bacteria there are present in a given quantity of a liquid such as water, milk, or blood. In this exercise the object is to separate the bacteria to obtain isolated colonies. For quantitative work, see Exercise LV.

42. **Work for this exercise.** Make a series of 3 agar plates, one of 3 gelatin plates, and one of 3 gelatin roll cultures (Esmarch rolls) from the bouillon culture of *B. coli communis* (§ 19). Place the agar plates in the incubator and the gelatin plates and rolls in a locker for that purpose.

Reëxamine all the cultures made in previous exercises and add to the laboratory notes a description of any changes in

their appearance. The notes should contain a detailed record of the cultures made in this exercise.

Read carefully the paragraphs in the text-books on making plate and roll cultures.

43. Making agar plate cultures. Take 3 large tubes of agar, stand them in a water bath, and boil until the agar is liquefied. Then cool by standing the tubes with a thermometer in a cup of water at a temperature of about 50°C . As the temperature rises, add a little cold water. When the temperature of the agar reaches that of the water, and the temperature of the whole has lowered to 40°C ., the agar is ready for use. For convenience in labeling, number the tubes 1, 2, and 3.

Place 3 sterilized Petri dishes on the leveling tripod and adjust it by means of a spirit level. With the wire loop proceed by the same method as followed in making bouillon cultures. Take one loopful of the bouillon culture, place it in agar tube 1 and mix by carefully shaking. Flame the wire and transfer 2 loopfuls of agar from tube 1 to tube 2 and mix as before. Again flame the loop and transfer 3 loopfuls from tube 2 to tube 3 and mix as with tubes 1 and 2. After the tubes are inoculated, pour the agar into the Petri dishes. In doing this remove the plug, carefully flame the mouth of the tube, and after quickly cooling, raise with the left hand the edge of the cover on one side of the Petri dish sufficiently to allow of inserting the mouth of the tube. After the agar is poured out of the tube replace the cover immediately. Label and number the Petri dishes to correspond with the dilutions in the tubes: thus, plate 1 is from tube 1, plate 2 is from tube 2, and plate 3 is from tube 3. Place the label near the edge of the cover. The Faber pencil for marking glass may be used instead of the gummed label. In making the dilutions it is important that the wire loop should be flamed after making each transfer.

44. Making gelatin plate cultures. These are prepared precisely as the agar plates, with these exceptions: (1) the

gelatin is liquefied at a temperature of 45°C ; (2) the plates when made are to be kept in the locker the same as the gelatin stab cultures; (3) in hot weather it is sometimes necessary to put a piece of ice in the reservoir under the glass plate on the leveling tripod to congeal the gelatin.

The directions given above for making the dilutions are applicable only when the original culture is moderately clouded. If there are comparatively few bacteria in the liquid, a larger quantity of the culture will be necessary. If there are many more, as in turbid bouillon or in slant-agar-culture cultures, it will be necessary to take a much smaller quantity for the first dilution. It is often desirable to make the first dilution in a tube of sterile water or bouillon instead of gelatin or agar, and to make 2 rather than 3 plates. It is sometimes desirable to make 4 or more cultures.

45. Making Esmarch roll cultures. For this purpose gelatin is ordinarily used. Agar does not adhere readily to the sides of the tubes, but is sometimes used. Take the desired number of large tubes of gelatin, liquefy, inoculate, label, and number the dilutions as in making gelatin plate cultures. Place a block of ice about 6 inches long in an agate-iron or glass tray. Melt a slight, nearly horizontal groove in the ice with a test tube containing hot media or water. The inoculated tubes are tipped and rolled so that the liquid gelatin moistens the inside of the tube to within about a centimeter of the plug. Then roll the tube rapidly in the groove on the ice until the medium becomes solid. The gelatin should not come in contact with the plug. In rolling the tube the plugged end should always project beyond the ice. (See illustration in text-books.)

EXERCISE IX

THE EXAMINATION OF PLATE CULTURES AND THE
MAKING OF SUBCULTURES FROM COLONIES

46. In practical bacteriologic work plate cultures are made use of in determining (1) the number of bacteria there is in a given substance, (2) the different species of bacteria present, and (3) the character of the growth in a colony of the organism in question. Other important facts, such, for example, as the relative number of each species of bacteria or the difference in the appearance of the surface and deep colonies, are learned through this process. The plate culture, therefore, is one of the most important single methods employed in isolating and studying bacteria.

47. Work for this exercise. Examine carefully and describe the plate cultures made in Exercise VIII. If the agar plates do not have colonies, or if the colonies are so numerous that they cannot be counted on any of the plates, make the cultures over again, and give an explanation in the notes of this exercise for the failure to obtain good results.

Make a hanging-drop preparation from a colony from an agar plate and one from a colony from a gelatin plate, and examine them microscopically. Describe the appearance of the bacteria in each.

Make a cover-glass preparation from each of the same colonies and stain each with carbol fuchsin. Examine each preparation carefully and make a drawing of a few of the isolated bacteria. Describe (§ 35) the appearance of the bacteria in these preparations.

Inoculate a tube of bouillon and one of agar from a well-isolated colony on one of the agar plates.

48. Suggestions for the examination of the plate and roll cultures. Observe the general appearance of the plates; note

whether the colonies are well isolated or run together (confluent); describe the appearance of the individual colonies (*a*) on the surface, (*b*) in the depth of the medium.

Indicate their shape (see § 51). Are the edges sharply defined? Is the margin even or irregular? Give their size (diameter in millimeters) and indicate their color (determine shade from a color chart¹) and consistence. Do the surface colonies adhere to the medium or can they be easily removed? Examine them with a low-power lens and describe the surface markings, if any. Also indicate the difference in color as observed with the unaided eye and with the microscope.

49. Estimating the number of colonies on plates. If the number of colonies is not large (not exceeding 100), they may all be counted and the exact number recorded. This may be done with the third plate. When the number is larger it is more convenient to divide the total area into smaller areas and count the number of colonies in each of several (20 to 40) of the small areas. Add these together and divide the sum by the number of areas counted; the quotient gives the average number on one area. Multiply this quotient by the number of areas containing colonies, and the product will be the number of colonies on the plate. This latter process, however, gives the approximate number only.

For dividing the area of the plate into smaller, equal areas, it is convenient to use Wolffhügel's counting apparatus. This was devised more particularly for square or oblong plates (Koch). In counting the colonies on the Petri dishes Parkes' ² scheme modified by Jeffers ³ is more suitable. It consists of a disk about 20 cm. in diameter, divided into areas of a square centimeter each. Place the Petri dish over the disk, taking care that it is centered.

¹ Saccardo, *Chromotaxia seu Nomenclator Colorum*.

² Parkes, *Journal of Pathology and Bacteriology*, Vol. IV, p. 173.

³ Jeffers, *Journal of Applied Microscopy*, Vol. I, No. 3, 1898.

Count the number of colonies in several (10 to 40) of the areas and multiply the mean number by the number of areas covered. This product gives the approximate number of colonies on the plate.

50. Making subcultures from colonies. Select the tubes of media to be used and flame the mouths as heretofore described. Select a colony as well isolated from all others as possible. With the left hand carefully raise the edge of one side of the cover of the Petri dish and, while holding it, touch the colony with the needle, replace the cover, take up the tube of medium and inoculate it. If bouillon is used first, a tube of agar or gelatin can be inoculated immediately afterward without recharging the needle. If more cultures are to be made, it is necessary to charge the needle again from the colony. If the plate is to be rejected, the cover may be entirely removed in the beginning. The newly inoculated tubes or subcultures should be labeled and treated according to the directions heretofore given for handling cultures. These inoculated tubes should be pure cultures. It sometimes happens, however, that what appears to be a single colony consists of the growths of two organisms. If these should be of different species, the cultures made from the colony would probably be impure. These impure growths (apparently single colonies) frequently develop on plate cultures exposed to the air for some time. Single particles of dust often carry two or more bacteria.

51. Chester's terminology for description of colonies.

1. Form of colonies. Plate culture.

Punctiform: dimensions too slight for defining form by naked eye, minute, raised, semispherical.

Round: of a more or less circular outline.

Irregular.

Elliptical.

Fusiform: spindle-shaped, tapering at each end.

Cochleate: spiral or twisted like a snail shell.

Amæboid: very irregular, streaming.

Mycelioid: a filamentous colony with the radiate character of a mold.

Filamentous: an irregular mass of loosely woven filaments.

Floccose: of a densely woolly structure.

Rhizoid: of an irregular branched, rootlike character, as in *Bact. mycoides*.

Conglomerate: an aggregate of colonies of similar size and form.

Toruloid: an aggregate of colonies like the budding of the yeast plant.

Rosulate: shaped like a rosette.

2. Detailed character of surface.

Smooth: surface even, without any of the following distinctive characters.

Alveolate: marked by depressions separated by thin walls, so as to resemble a honeycomb.

Punctate: dotted with punctures like pin pricks.

Bullate: like a blistered surface, rising in convex prominences, rather coarse.

Vesicular: more or less covered with minute vesicles, due to gas formation; more minute than bullate.

Verrucose: wartlike, bearing wartlike prominences.

Squamose: scaly, covered with scales.

Echinate: beset with pointed prominences.

Papillate: beset with nipple- or mamma-like processes.

Rugose: short, irregular folds, due to shrinkage of surface growth.

Corrugated: in long folds, due to shrinkage.

Contoured: an irregular but smoothly undulating surface, like the surface of a relief map.

Rimose: abounding in chinks, clefts, or cracks.

3. Internal structure of colony (microscopic).

Amorphous: without definite structure as below specified.

Hyaline: clear and colorless.

Homogeneous: structure uniform throughout all parts of the colony.

Homochromous: color uniform throughout.

Granulations or blotchings.

Finely granular.

Coarsely granular.

Grumose: coarser than the preceding, a clotted appearance, particles in clustered grains.

Moruloid: having the character of a *morula* segmented, by which the colony is divided into more or less regular segments.

Clouded: having a pale ground, with ill-defined patches of a deeper tint.

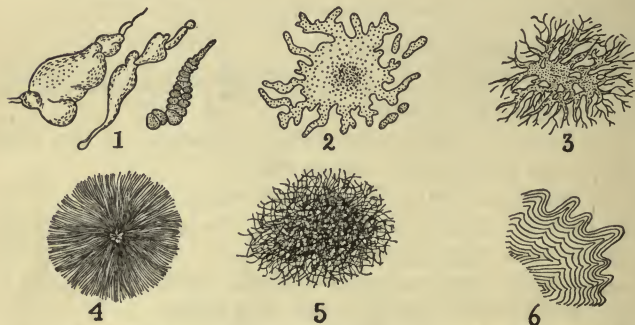


FIG. 4. Types of colonies: 1, cochleate; 2, amœboid; 3, rhizoid; 4, mycelioid; 5, filamentous; 6, curled structure.

4. Colony marking or striping (surface).

Reticulate: in the form of a network like the veins of a leaf.

Areolate: divided into rather irregular or angular spaces by more or less definite boundaries.

Gyrose: marked by wavy lines indefinitely placed.

Marmorated: showing faint, irregular stripes, or traversed by veinlike markings as in marble.

Rivulose: marked by lines, like the rivers of a map.

Rimose: showing chinks, cracks, or clefts.

Filamentous: as already defined.

Floccose: composed of filaments densely placed.

Curled: filaments in parallel strands, like locks or ringlets, as in agar colonies of *Bact. anthracis*.

5. Edges of colonies.

Entire : without tothing or division.

Undulate : wavy.

Repand : like the border of an open umbrella.

Erose : as if gnawed, irregularly toothed.

Lobate.

Lobulate : minutely lobate.

Auriculate : with earlike lobes.

Lacerate : irregularly cleft, as if torn.

Fimbriate : fringed.

Ciliate : hairlike extensions, radiately placed.

Tufted.

Filamentous : as already defined.

Curled : as already defined.

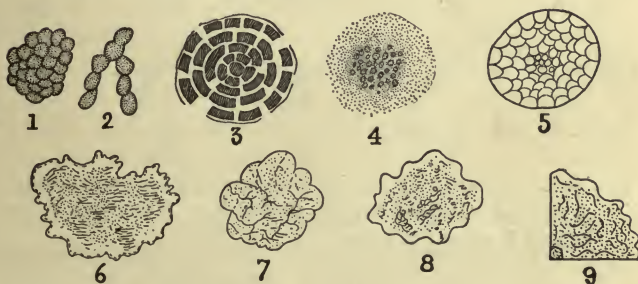


FIG. 5. Structure of colonies: 1, conglomerate colony; 2, toruloid colony; 3, alveolate structure; 4, grumose in center; 5, moruloid; 6, clouded; 7, reticulate; 8, marmorated; 9, gyrose.

6. Optical characters (after Shuttleworth).

Transparent : transmitting light.

Vitreous : transparent and colorless.

Oleaginous : transparent and yellow; olive to linseed oil colored.

Resinous : transparent and brown, varnish or resin colored.

Translucent : faintly transparent.

Porcelaneous : translucent and white.

Opalescent : translucent, grayish white by reflected light, smoky brown by transmitted light.

Nacreous : translucent, grayish white, with pearly luster.

Sebacious : translucent, yellowish or grayish white.

Butyrous : translucent and yellow.

Ceraceous : translucent and wax colored.

Opaque.

Cretaceous : opaque and white, chalky ; dull, without luster.

Dull : without luster.

Glistening : shining.

Fluorescent.

Iridescent.

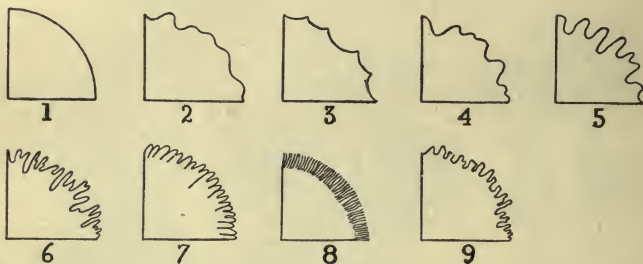


FIG. 6. Character of borders of colonies: 1, entire; 2, undulate; 3, repand; 4, lobate-lobulate; 5, auriculate; 6, lacerate; 7, fimbriate; 8, ciliate; 9, erose.

EXERCISE X

THE PREPARATION OF CERTAIN DIFFERENTIAL AND SPECIAL MEDIA

52. In studying the properties of bacteria it is desirable to cultivate them on a number of different media. Bouillon, agar, and gelatin are most commonly used, but others are necessary in determining the cultural peculiarities and important biochemic properties of the organism in question. The cultivation of bacteria upon these media may be regarded in the light of a test to determine the presence or absence of certain properties or powers possessed by the bacterium in question: thus, for example, whether the species in hand will coagulate the casein in milk, produce gas in media containing saccharose, grow on potato, etc. The number of these tests which have been used and recognized as important is quite large, but in a short course only those possessed of special differential value can be tried. In describing a new species or identifying any of the carefully described ones, it is important to know at least some of these cultural peculiarities and biochemic properties. For this reason it is necessary to learn the method of preparation and the use of certain of these media. The more important of such media are included in this exercise.

In addition to the above, a few species of bacteria require particular kinds of media for their diagnostic or most differential growth. Among these are the specific organisms of glanders, diphtheria, and tuberculosis. The preparation of these particular media will be considered in connection with the study of the organisms requiring them.

53. Work for this exercise. Prepare for culture media 5 tubes of potato, 5 tubes of milk, 5 tubes of litmus milk, 5 tubes of glucose agar, 5 tubes of glycerin agar, 3 fermentation and 5 small test tubes of bouillon containing glucose, the

same number and kinds of tubes containing lactose, and the same containing saccharose. (The agar and the sugar-free bouillon necessary in the work of this exercise will be furnished by the instructor.)

Read carefully the paragraphs in the text-books on the preparation and use of these media.

54. Preparation of potato for a culture medium. Select 3 medium-sized potatoes, thoroughly wash and rinse in boiled water, and cut out, with a cutter made for this purpose, cylinders from 3 to 4 cm. long (oblong rectangular pieces cut with a knife will do quite as well). Ordinarily 2 cylinders can be cut from each potato. These can be cut obliquely, giving 2 pieces each. All of the skin must be removed. Wash the potato cylinders in cold running water for 5 minutes (a longer time is preferable), place them in test tubes of the proper size (large or small according to size of cutter used), and add about 1 cc. of water to each tube. Sterilize them by discontinuous boiling or steaming for 20 minutes each day for 3 consecutive days. Wipe, label, and store in locker.

55. Preparation of milk for a culture medium. It is better that the cream be removed from the milk before it is used. To do this the fresh milk (about 100 cc.) is placed in a beaker and set in the ice box for from 10 to 15 hours. Then carefully remove the cream. It is well to filter the milk through a thin layer of absorbent cotton to remove any masses of cream that may be left. The reaction should be tested, and if strongly acid, should be rejected or made 1.5% acid to phenol-phthalein by the addition of $n/10$ sodium hydrate. Distribute the skimmed milk in small test tubes (5 cc. in each) and sterilize by discontinuous steaming in the same manner and for the same length of time as the potatoes. Wipe, label, and store the tubes in locker.

56. Preparation of litmus milk for a culture medium. This is prepared the same as the milk medium, with the addition of enough of an aqueous solution of litmus to impart a decidedly

blue color to the milk. Sterilize, wipe, label, and store the same as the milk. The litmus solution will be furnished.

57. Preparation of glucose (grape sugar) agar. Take 30 cc. of agar previously prepared (§ 18), liquefy, and add 1% glucose while hot. After thoroughly mixing, distribute it in small sterile test tubes. Sterilize, wipe, label, and store the same as ordinary agar.

58. Preparation of glycerin agar. Take 50 cc. of the agar previously prepared and add 5% of pure (c.p.) glycerin. Thoroughly mix it with the agar, after which distribute it in tubes. Sterilize, label, and store as ordinary agar.

59. Preparation of glucose bouillon. This is used in the fermentation tube. Take 100 cc. of sugar-free peptonized bouillon (§ 62) and add 1 gram of pure grape sugar (glucose). After it is dissolved and thoroughly disseminated through the bouillon by stirring or pouring, distribute the bouillon in 3 fermentation tubes, filling completely the closed branch and the open bulb about half full, and put 5 cc. in each of 5 small sterile test tubes. Sterilize by discontinuous steaming for 20 minutes each day for 3 consecutive days. The tubes should be wiped, labeled, and placed in the locker until needed for use.

60. Preparation of lactose bouillon. This is prepared by adding 1% of pure lactose (milk sugar) to the peptonized sugar-free bouillon. It is necessary that the bouillon used does not contain muscle sugar. After adding the lactose, which has been dissolved and thoroughly mixed in a few cubic centimeters of the bouillon, distribute in fermentation tubes and small test tubes, sterilize, label, and store the same as the glucose bouillon.

61. Saccharose bouillon. This is peptonized sugar-free bouillon to which 1% pure saccharose (cane sugar) has been added. It is prepared from bouillon free from muscle sugar in the same manner as lactose bouillon.

62. Preparation of sugar-free bouillon. Bouillon prepared by the ordinary method usually contains small quantities of

muscle sugar. To eliminate this the following method has been recommended.¹ Beef infusion is inoculated in the evening with a rich fluid culture of some acid-producing organism (*B. coli communis*) and placed in the incubator. The next morning the white of an egg is added, and the infusion is boiled and filtered. Peptone and salt are added as usual. It is boiled, filtered again, distributed in tubes or flasks as desired, and sterilized the same as bouillon (§ 12).

63. Preparation of acid agar. This is prepared in the same manner as ordinary agar (§ 18), with the omission of the sodium hydrate in the bouillon from which it is made.

64. Preparation of acid glycerin agar. Add 5 % glycerin to acid agar before sterilizing it.

65. Preparation of acid glycerin bouillon. This is prepared either as ordinary bouillon (§ 12) or as sugar-free bouillon (§ 62), with the omission of the alkali and the addition of 5 % c.p. glycerin.

66. Preparation of blood serum. When a small quantity is sufficient it can be obtained from a dog aseptically. The animal is properly tied on the operating table, etherized, the skin over the carotid or femoral artery is thoroughly disinfected and turned back, the artery exposed, a sterile glass canula inserted, and the blood collected in a sterile flask by means of a sterile rubber tube attached to the canula. After the serum is formed it can be drawn off with a sterile pipette and distributed in small sterile test tubes (5-7 cc. in each). It is well to set the liquid serum in an incubator for a few days to test its sterility. The tubes of liquid serum are inclined (the same as agar) and placed in a blood-serum sterilizer, or other chamber, in which the temperature can be raised to 70° or 75° C. until the serum has set. Store in a cool place.

If larger quantities of the blood are required, it is more convenient to collect it from bleeding animals in a slaughterhouse.

¹ Smith, *Journal of Experimental Medicine*, Vol. II (1897), p. 543.

In this case it is often necessary to sterilize the liquid serum after it has been distributed in tubes. This can be done in a water bath at 62°C. for 2 hours each day for 4 consecutive days.

67. Preparation of Loeffler's blood serum. This consists of 1 part neutral bouillon (prepared from meat) containing 1% grape sugar and 3 parts liquid blood serum. Mix and distribute in sterile test tubes, incline, and solidify the same as blood serum. The temperature should be about 75°C. , and the exposure will be necessarily longer than for the pure blood serum. When it is to be used for the cultivation of diphtheria organisms it can be set at a much higher temperature (80° to 100°C.). Label and store.

68. Preparation of egg medium. The whole egg is preferable. Carefully break the shell of the required number (3, 6, or more) of fresh eggs, drop the entire contents into a sterile beaker, and carefully stir with a sterile glass rod, care being taken to avoid air bubbles. After the egg is well mixed it is poured into test tubes (6 to 10 cc. in each) and sterilized by heating, preferably in a serum water bath at 70°C. for from 4 to 5 hours each day for 2 days. After sterilization the tubes, if test tubes, should be sealed. Before using, add a few drops of sterile water or, better perhaps, of 5% glycerin or of glucose to afford sufficient moisture. This is most used at the present time for the cultivation of tubercle bacteria (Dorset, *Am. Med.*, April 5, 1902).

69. Preparation of nitrate bouillon. Take peptonized bouillon 200 cc. Add potassium nitrate (0.5%) 1 gram. Dissolve the nitrate in the bouillon, put in tubes, and sterilize the same as bouillon.

The nitrate of sodium or ammonium may be substituted for that of potassium. The salt may be added in the proportion of from 0.1 to 1% to meet special demands.

For other methods and special media, see text-books.

70. Grouping of culture media. For convenience in reference and assignment of media, the culture media most commonly

employed in studying and differentiating species of bacteria have been arranged arbitrarily in groups. Large test tubes containing agar and gelatin for making plate cultures are not included in these groups.

Group A. Media commonly used.

A tube of bouillon.

A tube of sugar-free bouillon.

A tube of agar.

A tube of gelatin.

A tube of milk.

A tube of litmus milk.

A tube of potato.

Group B. Media favorable to determine the power of bacteria to ferment the sugars with the formation of acids.

A tube of bouillon containing 1 % grape sugar (dextrose, glucose).

A tube of bouillon containing 1 % milk sugar (lactose).

A tube of bouillon containing 1 % cane sugar (saccharose).

Group C. Media favorable for determining the production of gas.

A tube of agar containing 1 % grape sugar.

A tube of agar containing 1 % milk sugar.

A tube of agar containing 1 % cane sugar.

Group D. Media and tubes favorable for approximate gas analysis and the determining of the aërobic or anaërobic tendencies.

Fermentation tube containing 1 % grape-sugar bouillon.

Fermentation tube containing 1 % milk-sugar bouillon.

Fermentation tube containing 1 % cane-sugar bouillon.

The fermentation tubes containing bouillon with sugars may be substituted for the media containing sugars in Groups B and C if desired.

Group E. Media either necessary for or especially desirable for the cultivation or differentiation of certain pathogenic bacteria.

Acid agar (in small tubes).

Acid glycerin agar (in small tubes).

Acid glycerin bouillon (in small tubes).

Blood serum (dog) solidified at 70° to 75° C. (ground-glass-capped tubes).

Loeffler's blood serum (usually small tubes).

Egg medium (Dorset).

EXERCISE XI

INOCULATING SPECIAL MEDIA AND EXAMINING CULTURES

71. Work for this exercise. Inoculate, from a culture furnished of *B. proteus vulgaris*,¹ a tube of potato, one of milk, one of litmus milk, one of glucose agar, a fermentation and test tube of glucose, one each of lactose and of saccharose bouillon. Label each and place in the incubator.

Stain a preparation with alkaline methylene blue, one with carbol fuchsin, and one with an aqueous solution of gentian violet from the bouillon and agar cultures (§ 47). Make a careful comparison of the preparations and note any difference in the appearance of the bacteria or in the intensity of the stain. Preserve as a permanent specimen, to accompany the notes, a preparation stained with each of the dyes.

Prepare the aqueous solution of gentian violet (§ 38).

(For methods of making anaërobic cultures, see Exercise XXXIX.)

72. The inoculation of glucose agar to determine the power of the organism to produce gas. Boil the tube of glucose agar in an open water bath until it is liquefied, then cool it down to a temperature of 40° C. and inoculate it with a loopful of the culture, carefully stir the agar with the loop, after which solidify it as quickly as possible. Label and stand in the incubator.

73. The use of media containing the sugars. The sugars are employed as tests to determine whether or not the bacteria in question will ferment them, producing acids. Some bacteria will produce gas as well as acids. The latter is determined in the sugar-agar tubes.

In the fermentation tubes we can determine both of these properties and also the quantity of gas set free. It is easier,

¹ Or any other gas-producing bacillus.

however, to determine the acid and gas production in the test tubes than to use the fermentation tubes, and it is cheaper. It is convenient, therefore, to use these tubes with the sugar media as follows :

1. If to determine the power of the organism to produce gas, use only the agar tubes.

2. If to determine the power of the organism to ferment sugars, producing acids, use only test tubes of bouillon.

3. If to determine the quantity of gas produced and approximately its composition, use the fermentation tube. In this exercise all three are called for.

EXERCISE XII

THE EXAMINATION OF CULTURES ON SPECIAL MEDIA,
WITH A STUDY OF THE GAS PRODUCTION

74. As certain of these media are used to determine the effect of the bacteria upon them, it is important to observe very carefully not only the appearance of the growth of the bacteria but also their effect, if any, upon the medium on or in which they are growing. This is especially noticeable in the milk, litmus milk, and sugar bouillon cultures. The changes here are largely due to the action of the bacteria on the sugars or their power to produce alkali.

The knowledge of the powers of a given species of bacteria to produce gas when grown in a medium containing sugar is also quite important. It is desirable to determine both the quantity of gas and its relative composition. Chemical analyses have shown that in all cases tested the gas resulting from the fermentation of the sugar consists of a mixture of hydrogen (H) and carbonic acid gas (CO_2), with mere traces of other gases. It is important to know also the quantity of gas produced with the various sugars, especially glucose, lactose, and saccharose. To determine simply whether an organism will produce gas, it is only necessary to inoculate it into tubes of liquid agar containing the various sugars; but if the quantity of gas is to be determined, the fermentation tube is the most convenient apparatus to use. In some cases the gas formation is one of the most striking differential properties, as will be seen in the study of hog-cholera and typhoid bacilli.

REFERENCES. For a discussion of the gas production and use of the fermentation tube, see Smith, *Wilder Quarter-Century Book*, 1893, p. 187; for the chemical formulæ, see Novy, *Laboratory Work in Bacteriology*, 1899.

75. Work for this exercise. Examine and describe the cultures made on the special media in Exercise XI.

Examine the bacteria on the potato culture microscopically (1) in the fresh condition (hanging-drop preparation) and (2) in a stained (carbo-fuchsin) cover-glass preparation. Describe the appearance of the bacteria (§ 35). Examine the fermentation tubes and indicate the quantity of gas.

76. A few points to be observed in studying cultures on special media. (a) *Potato*. Note carefully the extent and color of the growth and its consistence.

(b) *Milk*. Note whether or not the general appearance and odor of the milk have been changed, and observe whether the casein has been coagulated, giving a firm, solid coagulum, or precipitated. Is the coagulum covered with a liquid (serum)? if so, is it clear or milky? Is there any appearance suggestive of saponification? Determine its consistence, chemical reaction as indicated by litmus paper (§ 27), and give as descriptive a name as possible to its odor.

(c) *Litmus milk*. Note especially whether there has been any change in color since inoculation. Observations similar to those on the plain milk should also be made.

(d) *Glucose agar*. Note the character and number of colonies within the agar, and the presence, if any, of gas bubbles. Are there few or many of them?

(e) *Bouillon containing sugars in test tubes*. Note carefully the appearance of the bouillon, but especially its chemical reactions as indicated by the litmus paper (§ 27).

(f) *Bouillon containing sugars in fermentation tubes*. Observe the character of the growth in each tube (whether the liquid is faintly or heavily clouded, turbid, contains flakes, etc.), — in (1) the open bulb and in (2) the closed branch of the fermentation tube. Note the presence or absence of a membrane on the surface of the liquid in the open bulb. Is there a sediment in the bottom of the tube? If so, describe its general appearance and consistence. Note the presence or

absence of gas in the closed branch. Indicate the quantity and note its rate of formation from time to time. Test the reaction of the liquid with litmus paper.

The fermentation tubes are also used to enable one to determine the quantity and kinds of gases produced and the aërobic or anaërobic tendencies of the organism.

In studying the cultures in the fermentation tubes they should be examined each day and the quantity of gas indicated. Note the bubbles of gas rising through the liquid to the top. When the gas production has ceased, the liquid begins to clear near the surface in the closed branch. The final record should not be made until this occurs. The reaction of the culture should be determined and noted at this and the next exercise. Explain the chemical formulæ for the production of the gas, and if the reaction changes, give the explanation.

77. Determination of the quantity of gas. It is desirable to determine the quantity of gas collected in the closed branch in terms of the capacity of the tube. To do this, measure the length of the closed branch and the length of that portion of the tube filled with gas. Thus, if the length of the tube is 10 cm. and the length of the portion filled with gas is 3 cm., the gas fills three tenths of the branch. This cannot be determined until the gas formation has ceased, which sometimes requires several (4 to 6) days. The closed branch of the fermentation tube should be straight and the connecting part of the tube should be narrow. If the tube stands too long before the quantity of gas is determined, some of it is liable to be absorbed.

78. To determine the ratio of CO_2 to H in the gas produced. This can be approximately determined by the use of caustic soda. Remove the plug from the fermentation tube and fill the open bulb with a 2% solution of caustic soda. Place the thumb tightly over the open end of the tube and tip it up so that the gas will pass through the liquid and come into the

open bulb. It is then returned. This should be repeated several times. Remove the thumb when the open bulb is full, and the liquid will rush up into the closed branch to fill the space occupied by the CO_2 which has been absorbed by the caustic soda. Measure the portion of the tube first occupied with gas and now filled with the liquid. This will indicate the quantity of CO_2 . The remainder of the gas is H. (There are also traces of other gases.) Its explosive property can be tested by filling the open bulb with water, covering it with the thumb and again bringing the gas to the open bulb, holding it close to a flame, and removing the thumb. A distinct explosion will be heard.

The ratio of CO_2 to H can be determined from the measurements. Thus the total amount of gas in the closed branch = 5 cm. The amount absorbed (CO_2) = 2 cm. The remaining gas, or 3 cm., = H. The ratio of CO_2 to H is, therefore, as 2 : 3, or $\text{CO}_2 : \text{H} :: 2 : 3$.

EXERCISE XIII

THE EXAMINATION OF CULTURES (*continued*)

79. Work for this exercise. Reëxamine the cultures made on special media and make notes on all changes which have occurred in their appearance.

Examine microscopically in hanging-drop preparations the bacteria from the glucose bouillon culture.

Make a stained cover-glass preparation from the milk culture. Stain with carbol fuchsin.

Reëxamine all of the cultures previously made and make careful notes of any changes that have occurred in their appearance.

Measure the gas in the fermentation tubes and determine the ratio of CO_2 to H.

80. Making cover-glass preparations from milk cultures. Spread as thin a film of the milk culture as possible on the cover glass and allow it to dry in the air. Immerse the preparation in a watch glass or other receptacle containing a few cubic centimeters of ether and absolute alcohol in equal parts, which dissolves out the fat and fixes the film to the cover glass at the same time. Then remove and, after the ether and alcohol have evaporated, stain as usual. The amount of albumen in the milk will usually cause a heavy background, which will require decolorizing with alcohol or weak acetic acid.

EXERCISE XIV

THE CLASSIFICATION OF BACTERIA

81. The term "bacteria" is a general and popular one used to designate a large group of microscopic plants, the *Schizomycetes*. These organisms, which are widely distributed in nature, have been classified into a certain few families and genera most of which have a large number of species. Many of these species have been described, but there are many which have not. In classifying the bacteria, the genera are based on morphologic characters; while, as a rule, the species are determined by means of their biochemic, physiologic, or pathogenic properties. Several systems of classification have been proposed, but the one which seems to be the most satisfactory is by Migula. This classification utilizes the morphology to such good advantage that its adoption seems desirable. It requires, however, some serious changes in the accustomed nomenclature; but this is true of any logical system. The restoration of the genus *Bacterium* and the assigning to it of all non-motile, rod-shaped organisms change the genus of some of our most common pathogenic bacteria from *Bacillus* to *Bacterium*. The most conspicuous of these are the bacilli of tuberculosis, glanders, and diphtheria, all of which are placed in Migula's classification in the genus *Bacterium*. The families and genera recognized by him are appended. (See lecture notes and text-books on the classification and morphology of bacteria.)

82. Work for this exercise. Read the references on the morphology and classification of bacteria.

Reject all the cultures made and clean the tubes and Petri dishes [§ 3, (f)].

Inoculate a tube of bouillon (from cultures which will be furnished) with each of the following genera of bacteria: (1) a streptococcus, (2) a micrococcus, (3) a sarcina.

83. Migula's classification of bacteria.

FAMILIES

- I. Cells globose in a free state, not elongating in any direction before division into 1, 2, or 3 planes 1. COCCACEÆ
- II. Cells cylindrical, longer or shorter, and only dividing in 1 plane, and elongating to twice the normal length before the division.
 1. Cells straight, rod-shaped, without sheath, nonmotile, or motile by means of flagella 2. BACTERIACEÆ
 2. Cells crooked, without sheath 3. SPIRILLACEÆ
 3. Cells inclosed in a sheath } 4. CHLAMYDOBACTERIACEÆ
 4. Cells destitute of a sheath, united into threads, motile by means of an undulating membrane 5. BEGGIATOACEÆ

1. GENERA BELONGING TO THE FAMILY COCCACEÆ

Cells without organs of motion.

- a. Division in 1 plane 1. *Streptococcus*
- b. Division in 2 planes 2. *Micrococcus*
- c. Division in 3 planes 3. *Sarcina*

Cells with organs of motion.

- a. Division in 2 planes 4. *Planococcus*
- b. Division in 3 planes 5. *Planosarcina*

2. GENERA BELONGING TO THE FAMILY BACTERIACEÆ

Cells without organs of motion 1. *Bacterium*

Cells with organs of motion (flagella).

- a. Flagella distributed over the whole body 2. *Bacillus*
- b. Flagella polar 3. *Pseudomonas*

3. GENERA BELONGING TO THE FAMILY SPIRILLACEÆ

Cells rigid, not snakelike or flexuous.

- a. Cells without organs of motion . . . 1. *Spirosoma*

b. Cells with organs of motion (flagella).

(1) Cells with 1, very rarely 2-3, polar flagella 2. *Microspira*

(2) Cells with polar flagella, in tufts of from 5 to 20 3. *Spirillum*

Cells flexuous 4. *Spirochæta*

4. GENERA BELONGING TO THE FAMILY CHLAMYDO-BACTERIACEÆ

I. Cell contents without granules of sulphur.

a. Cell threads unbranched.

(1) Cell division always only in 1 plane 1. *Streptothrix*

(2) Cell division in 3 planes previous to the formation of conidia.

(*a*) Cells surrounded by a very delicate, scarcely visible sheath (marine) 2. *Phragmidiothrix*

(*b*) Sheath clearly visible (in fresh water) 3. *Crenothrix*

b. Cell threads branched (pseudo-branches) 4. *Cladothrix*

II. Cell contents containing sulphur granules 5. *Thiothrix*

5. GENERA BELONGING TO THE FAMILY BEGGIATOACEÆ

Only one genus known (*Beggiatoa* Trev.), which is scarcely separable from *Oscillaria*. Character as given under the family.

Of these genera *Streptococcus*, *Micrococcus*, *Bacterium*, *Bacillus*, *Microspira*, and *Spirillum* contain the most important of the pathogenic bacteria. The familiar genus *Staphylococcus* of older classifications is included in the genus *Micrococcus* by Migula. It is important that the distinguishing characters of these genera be thoroughly learned.

REFERENCES. Migula, Die natürlichen Pflanzenfamilien, Lieferung 129, Leipsic, 1896. Migula, System der Bakterien, 1897. Fischer, Jahrbücher für wissenschaftliche Botanik, Band XXVII, Erstes Heft.

EXERCISE XV

THE MORPHOLOGY OF STREPTOCOCCUS, MICROCOCCUS,
AND SARCINA

84. Genera among bacteria are based on the gross morphology of the organisms. This is very largely true of all classifications. It is highly important, therefore, that the generic characters should be thoroughly learned. While the descriptive differences between a micrococcus and a bacterium seem to be clear, there are many organisms where it is not so easy to decide in which genus to place them. The almost constant appearance of unexpected bacteria in septic infections and in diseased organs renders it exceedingly desirable that one should understand the fundamental elements of classification. We must remember that the problems of the practitioner are not all centered about known pathogenic forms like the organisms of tuberculosis and diphtheria; but they have to do with a great host of infecting bacteria, of which we know as yet but very little.

85. Work for this exercise. Carefully describe each of the bouillon cultures made in Exercise XIV.

Prepare and examine a hanging-drop preparation from each of the cultures, and describe the appearance (form) of the organisms in each. Indicate the morphologic characters by which each genus can be differentiated from the others.

Make a cover-glass preparation from each culture and stain with an aqueous solution of methyl violet (§ 38). Make a careful microscopic examination of each preparation and describe the bacteria in each.

Make careful notes on the appearance of the bacteria in each preparation and preserve a specimen of each to accompany the notes.

Inoculate a tube of bouillon from cultures (furnished) of each of the following genera of bacteria : (1) a bacterium, (2) a bacillus (3 cults), (3) a spirillum.

(Select species of bacilli that illustrate slow and rapid motility and spores.)

EXERCISE XVI

THE MORPHOLOGY OF BACILLUS

86. The bacilli which are to be studied in this exercise exhibit in addition to the rod-shaped bodies the essential morphological variations of this genus, viz. number of flagella and spores. The two latter are held in common with the bacterium. The staining of the organs of locomotion (flagella) and the spores will be taken up in separate exercises.

87. Work for this exercise. Carefully examine and study the cultures made in Exercise XV, following the directions given for the examination of cultures and preparations in that exercise.

Measure carefully with the filar micrometer the length and thickness of 8 individual bacteria in one of the stained preparations. Record the measurements in microns (written μ). (For the use of the micrometer, see Appendix, also chapter on magnification and micrometry in *The Microscope*, by Professor S. H. Gage.)

State fully in the notes the generic characters of the genus *Bacillus*.

Inoculate a tube of bouillon and one of agar from each of the cultures (which will be furnished) of a *Bacterium* and of a *Spirillum*.

Inoculate a tube of agar with *B. subtilis* for Exercise XVIII.

EXERCISE XVII

THE MORPHOLOGY OF BACTERIUM AND SPIRILLUM

88. Work for this exercise. Examine very carefully and describe fully the cultures of the *Bacterium* and of the *Spirillum* made in the last exercise.

Make and examine, microscopically, hanging-drop and stained cover-glass preparations from each of the cultures. Describe the appearance of the individual bacteria in each.

Make a drawing magnified 1000 diameters of a few individuals from each of the stained preparations from the agar cultures.

State fully the morphology of these two genera and mention the differential characters between the genera *Bacillus* and *Bacterium*.

Inoculate a tube of agar with *B. cholerae suis* or *B. typhosus* for flagella staining in Exercise XIX.

89. Making drawings of bacteria with a definite magnification. In measuring the bacteria we obtain the dimensions in microns or in units of $1/1000$ of a millimeter. In making a drawing, therefore, showing them magnified 1000 diameters, it is simply necessary to represent each micron by 1 millimeter. Thus, if the organism is 2.5μ in length and 1μ broad, the drawing should be 2.5 mm. long and 1 mm. broad. If the drawing is to represent the organism magnified 500 diameters, then each micron should be represented by 0.5 mm. For this purpose a metric rule and a pair of dividers are necessary.

EXERCISE XVIII

STAINING SPORES

90. In certain species of bacteria and under suitable conditions there appear within the bacteria highly refractive bodies known as spores. The formation of spores is restricted to certain species. The spores are oval in form, and in old cultures they may often be found outside of the bodies of the organisms which produce them. They possess the power of resisting drying, heat, and unfavorable environment much longer than the bacilli themselves. They do not stain by the usual methods employed in staining bacteria, so special methods are required. Several processes have been proposed, but the one here given seems to be quite as efficient as any of the others.

Bacillus subtilis, or the hay bacillus, is one of the most widely distributed species of bacteria. It develops spores which can be readily detected either in fresh or stained preparations from cultures.

REFERENCES. Methods for staining spores in text-books.

91. Work for this exercise. Examine and carefully describe the culture of *Bacillus subtilis* made in Exercise XVI.

Make a hanging-drop preparation from the bouillon and one from the agar culture and examine them microscopically. Describe the bacilli and observe carefully the appearance of the spores both within and without the organisms.

Make a cover-glass preparation from each culture and stain with alkaline methylene blue. Examine carefully and note the appearance of spores which remain unstained. Make a drawing of a few of the bacteria containing spores.

Make a few (about 3) cover-glass preparations and stain them for spores.

Prepare water suspensions for staining flagella as described in (§ 95).

92. A method for staining spores. Make a cover-glass preparation, dry, and flame as already described. Take the preparation by the edge with the fine forceps, cover the film surface with carbol fuchsin, and hold the preparation over the gas flame until steam is given off; then remove it for a few seconds and heat again. Repeat the heating three or four times. After the stain has acted for from 3 to 5 minutes, rinse the preparation in water and decolorize it by immersing it in a watch glass containing about 3 cc. of 1% solution of sulphuric acid or 95% alcohol. After about one half minute remove the preparation and rinse it thoroughly in water. If it is not decolorized, repeat the bleaching process. This removes the coloring matter from the bodies of the bacteria, but leaves it in the spores. After thoroughly washing the preparation, counterstain it with a saturated aqueous solution of methylene blue for about 30 seconds, rinse in water, and examine. The spores should be stained red (with the fuchsin) and the rest of the organism should be colored blue.

There is a very satisfactory method recommended by Möller. For this and other methods for staining spores, see text-books on bacteriology.

EXERCISE XIX

STAINING THE FLAGELLA ON MOTILE BACTERIA

93. The motile bacteria are provided with a variable number of long, hairlike appendages or flagella. These are invisible in the fresh preparation, and they do not stain by the ordinary methods. By special staining processes, however, their presence can be detected. Several methods have been proposed for staining these filaments, but nearly all of them are based on the use of a mordant. Curiously enough the value of each of these methods seems to rest largely on the skill of the individual using them, as some workers succeed with one method while others fail with it but obtain excellent results with one of the other processes. Although the flagella are known to be the organs of locomotion, they do not seem to be of any special morphological value in differentiating closely related species. They are, however, elements in the structure of motile bacteria, and their demonstration is much to be desired.

REFERENCES. Chapters on staining flagella in standard textbooks. Moore, A Review of the Methods for Staining Flagella on Motile Bacteria, *Am. Monthly Mic. Journal*, Vol. XII (1891), p. 15. Moore, The Character of Flagella, etc., *Wilder Quarter-Century Book*, p. 339. Loeffler, *Centralblatt für Bakteriologie*, etc., Bd. VI (1889), S. 209. Ferrier, *Achives de Méd. Exp. et d'Anat. pathologique*, T. VII (1895), p. 58. Van Ermengem, reviewed in *Centralblatt für Bakteriologie*, etc., Bd. XV (1894), No. 24. Johnston and Mack, *Am. Med.*, Vol. VII, p. 754.

94. Work for this exercise. Make a cover-glass preparation from the growth on the agar culture of *Bacillus cholerae suis* made in Exercise XVII and stain it with carbol fuchsin. Preserve this to compare with preparations stained for the purpose of demonstrating the flagella.

Clean about 10 cover glasses after the special method for flagella staining (§ 4). Make about 5 films on these from the

water suspension prepared at the last exercise and stain for flagella. Use Johnston's and Mack's modified method, with Loeffler's mordant and stain. The films should not be heated either before or during the staining process, but if it does not succeed, Loeffler's process may be tried.

95. Johnston's and Mack's modified method. (*a*) *Preparation of films.* Make a culture of the organism to be stained on slant agar and incubate for from 18 to 24 hours. Prepare a tube with 6 to 8 cc. of sterile water, and keep it in the incubator until it is of the same temperature. With a sterile platinum loop scrape away some of the growth from the agar surface, using care not to remove any of the agar, and rinse it off carefully in the tube of water previously prepared for this purpose. There should be enough to impart to the water a faint cloudiness. This should be done in a warm room and with considerable care. Replace this tube in the incubator and the bacilli will distribute themselves quite evenly through the water, but any clumps or masses settle to the bottom. The tube is left in the incubator for from 2 to 3 days before preparing the films. Place a tray of properly prepared cover glasses in the incubator to warm; then, still in the warm room, with a platinum loop put a drop or two from the tube on each cover (§ 4). Replace the tray in the incubator until the water has evaporated, when the films are ready to stain. The films require no fixing other than by the mordant. The small amount of organic matter in films prepared in this way gives but little background when stained.

(*b*) *Mordants and stains.* Different mordants and staining solutions may be used. Those of Loeffler or Pitfield give the most uniform and satisfactory results.

LOEFFLER'S MORDANT

Twenty per cent aqueous solution tannic acid . . .	10 cc.
Saturated aqueous solution iron sulphate . . .	5 cc.
Saturated alcoholic solution basic fuchsin . . .	1 cc.

Mix, let stand two or three hours, and filter.

Tannic acid solution should be freshly prepared, but the iron sulphate solution is better if it stands until it begins to turn brownish by oxidation, but it should not be too old. If when this mordant is used it gives a precipitate, filter again. When properly prepared it should have much the same color as a solution of hematoxylin.

LOEFFLER'S STAIN (ZIEHL'S CARBOL FUCHSIN)

Saturated alcoholic solution basic fuchsin . . .	2.5 cc.
Five per cent carbolic acid	20 cc.

If not clear, add fuchsin solution drop by drop until it clears, then filter.

PITFIELD'S MORDANT

Ten per cent aqueous solution tannic acid . . .	10 cc.
Saturated aqueous solution mercuric chloride . .	5 cc.
Saturated aqueous solution potassium alum . .	5 cc.
Ziehl's carbol fuchsin	5 cc.

Mix, let stand two or more hours, and decant clear fluid or filter.

PITFIELD'S STAIN

Saturated aqueous solution potassium alum . .	10 cc.
Saturated alcoholic solution gentian violet . .	2 cc.

Mix, let stand two or more hours, and filter.

Saturated alcoholic solution of methyl violet, basic fuchsin, or methylene blue can be substituted for gentian violet in the above formula with equally good results.

With a pipette apply to a film all the mordant the cover glass will hold, allow it to act two or three minutes without heating, and rinse thoroughly in clean water ; apply the stain in the same manner, allow it to act two or three minutes without heating, rinse well, and examine in water, or dry and mount in balsam.

All these solutions should be freshly prepared. Considerable care in washing after the mordant will be well repaid by insuring a cleaner background.

Around the edge where the drop was applied to the cover glass a heavy line of bacteria will be found, and if the right amount of culture was added to the water, many will be found scattered within the ring, some of them isolated so they can be easily studied. A little practice with this will enable one to make good preparations altogether free from background.

96. Staining the flagella by Loeffler's method. Place 2 loopfuls of sterilized distilled water or normal salt solution on the center of the cover glass. Gently touch the surface growth on the agar culture with the end of the platinum needle and immerse it in the water on the cover glass without spreading the drop. The impregnated needle should carry bacteria enough for 3 or 4 preparations. Then place the tray of cover glasses in the incubator to dry. The bacteria become disseminated throughout the water by means of their power of locomotion. When dry they are ready for the staining treatment.

The bacteria are fixed to the cover glass by holding them, film upward, between the thumb and forefinger, over a gas flame for about a minute. They are then treated with the following mordant.

Tannic acid, 20 % solution	10 cc.
Sulphate of iron, saturated solution	5 cc.
Fuchsin, saturated alcoholic solution	1 cc.

This should be filtered before using.

Place the fixed cover-glass preparation in a large test tube, cover it with the mordant, and carefully heat over a gas flame or in a water bath until steam is given off. Allow the mordant to act for from 3 to 5 minutes. Then remove the cover glass with a bent wire loop and fine forceps and thoroughly rinse it in water. Then place it in a similar tube and cover with carbol fuchsin for staining. Heat this as the mordant was heated and allow the stain to act for from 5 to 10 minutes. Remove the cover glass as before and thoroughly rinse in water. If the stain is too deep, decolorize by rinsing the preparation

for a few seconds in alcohol and again in water. It is then ready for the microscopic examination in water, or it may be allowed to dry and then be mounted in balsam. If the first preparation fails, add 2 drops of a 10% solution of sulphuric acid to the mordant.

The flagella should appear as fine, hairlike appendages radiating from the bacteria.

97. Staining the flagella by Van Ermengem's method. The films are prepared as described above. Three solutions are necessary.

SOLUTION A (FIXING BATH)

Osmic acid, 2 % solution	1 part
Tannin, 10-25 % solution	2 parts

Place the films in this for 1 hour at room temperature or heat in an oven for 5 to 15 minutes at 55° C. Wash the preparation with distilled water, then with absolute alcohol for from 3 to 4 minutes, and again very thoroughly in distilled water. It is now ready to treat with Solution B.

SOLUTION B (SENSITIZING BATH)

This is a 5% solution of silver nitrate in distilled water. Allow the films to be in this for from 2 to 3 minutes. Then without washing transfer to Solution C.

SOLUTION C (REDUCING AND STRENGTHENING BATH)

Gallic acid	5 grams
Tannin	3 grams
Fused potassium acetate	10 grams
Distilled water	350 cc.

Keep in this for from 1 to 1½ minutes. Wash, dry, and mount. It will also be found an advantage to use a fresh supply of Solution C for each preparation, a small quantity being sufficient. If overbrowned, the background will be too deeply stained; if underbrowned, the flagella will be too faint.

EXERCISE XX

STAINING TUBERCLE BACTERIA (BACILLI)

98. The stained tubercle bacteria possess, because of the layer of fatty acids covering them, the power of retaining the coloring matter even when treated with a strong decolorizer, such as a solution of sulphuric or nitric acid. On this account staining has a high differential value which is made use of in identifying this organism. Thus in the examination of sputum in cases of suspected tuberculosis the object is to determine the presence of tubercle bacteria. As this organism is not easily cultivated, the staining process is very largely depended upon in making a differential diagnosis.

99. Work for this exercise. Make 4 cover-glass preparations from a culture of tubercle (furnished). Stain 2 of them with tubercle stain and carefully describe the appearance of the bacteria and illustrate with a few drawings.

Stain 2 of the preparations after Gabbett's method.

Stain a cover-glass preparation of tubercular sputum (furnished).

For the next exercise liquefy two large tubes of agar and two of gelatin and pour them into Petri dishes. After the medium has solidified remove the covers of the Petri dishes and expose one of each to the air for five minutes and one of each for ten minutes. Return the covers and place the agar plates in the incubator and the gelatin ones in the locker. When these plates are examined in the next and subsequent exercises there will be a colony for each bacterium that fell upon the medium from the air. It will be necessary to look out for impure or mixed colonies, as two or more organisms may have fallen together.

Read the directions in the text-books for staining tubercle bacteria (bacilli).

100. Staining tubercle bacteria. Prepare the cover-glass preparations from the culture of tubercle bacteria and flame them as already described. Stain in fresh carbol fuchsin. Place a few drops of the stain on the film side of the cover glass and hold it over a flame with forceps until steam is given off. Allow the hot stain to act for from 3 to 5 minutes, or the preparation may be floated on the carbol fuchsin in a watch glass without heat. In this case it is allowed to act for from 10 to 15 minutes. The preparation is then rinsed in water and decolorized by treating it with a 10 % solution of nitric or sulphuric acid for from $\frac{1}{4}$ to 1 minute. It is again rinsed in water, when it is ready for examination. It can be dried and mounted permanently in balsam. The tubercle bacteria should be stained a deep reddish color. All other bacteria or animal tissue in the preparation should be unstained. If desired, a counterstain, such as alkaline methylene blue, may be used after decolorizing; that is, the preparation should be again stained for about 1 minute in alkaline methylene blue, rinsed in water, and examined as before. In these preparations the tubercle bacteria are red and the other organisms and cells are blue. A counterstain is of no value in preparations made from pure cultures or for simple diagnostic purposes. When a counterstain is desired Gabbett's decolorizing and counterstaining solution is very convenient.

GABBETT'S SOLUTION

Methylene blue (powder)	2 grams
10 % sulphuric acid	100 cc.

After staining with the carbol fuchsin treat the preparations with this mixture until the film has a faintly bluish tint. This solution decolorizes and counterstains at the same time. This organism, like some other pathogenic bacteria, takes the Gram stain.¹

¹ See Novy's *Laboratory Work in Bacteriology*, p. 289, for a list of such organisms.

EXERCISE XXI

A STUDY OF CERTAIN SAPROPHYTIC BACTERIA

101. It is desirable to have a definite knowledge concerning the characters and properties of the commonly encountered species and groups of saprophytic bacteria. It is likewise important to understand the method of identifying species. For these reasons a few exercises on saprophytic bacteria, especially from air, milk, and water, have been introduced.

102. Work for this exercise. Examine and carefully describe the cultures made by exposing agar and gelatin plates to the air in the last exercise. Determine the number of different colonies and carefully describe each. Make a microscopic examination (hanging-drop) of the bacteria in one of each of the different kinds of colonies and determine its genus.

Make for examination in the next exercise a series of three plate cultures in gelatin and one of two plates in agar from a sample of milk furnished. The milk will be either freshly drawn in sterile flasks or samples of market milk.

103. Identifying species of bacteria. The genera of bacteria are determined by the morphology. Thus a spherical organism is a *micrococcus*, a motile, rod-shaped one is a *bacillus*, and a nonmotile, rod-shaped one a *bacterium*. Each genus has a large number of species. This requires some method by which bacteria which look exactly alike under the microscope may be differentiated provided they are different. This method consists in the study of the growth of these bacteria on the different media and possibly their effect upon small animals. For example, the *B. typhosus* and *B. coli communis* look so nearly alike that one could not be sure of a difference microscopically; *B. coli communis* coagulates milk, *B. typhosus* does not; *B. coli communis* produces gas in glucose media, *B. typhosus* does not. Knowing these properties and having these

cultures we could readily tell the one from the other. To identify species, therefore, one must compare the cultural characters of the organism in question with the description of the species already known. As new media are constantly being introduced, one often finds that the descriptions given in text-books and manuals of bacteriology are very brief and, as compared with modern requirements, insufficient to identify the species. This has resulted in the listing of a very large number of species that are very difficult if not impossible to identify. With pathogenic bacteria the somewhat specific action on experimental animals affords much aid in their identification. For further explanations, see text-books. Matzuschita's *Bacteriologische Diagnostik* is especially helpful in diagnosing species.

EXERCISE XXII

A STUDY OF BACTERIA IN MILK

104. It is desirable to understand somewhat clearly the bacterial contents of milk and to know something of the physiological properties of these bacteria. For this reason it is desirable to study though but briefly the bacteria in ordinary market milk.

REFERENCES. Russell, Dairy Bacteriology ; also one by Conn and one by Grotenfelt. Hunziker, Germicidal action in cow's milk, Bulletin No. 197, Cornell Univ. Exp. Station. Ward, The invasion of the udder by bacteria, Bulletin No. 178, *Ibid.* Park, Bacterial contamination of the milk of our cities, The N.Y. Univ. Bulletin of the Med. Science, Vol. I. Moore, Bacteria in milk, Report of the Com. of Agriculture of N.Y., 1902.

105. Work for this exercise. Examine the plate cultures made from milk. Describe the different kinds of colonies and state approximately the number of each. Examine microscopically the bacteria in one of each kind of colony and determine its genus.

Inoculate a tube of milk and one of gelatin from each of three different kinds of colonies, stating the genus of the bacteria in each.

Inoculate Group A of media from a culture of *B. prodigiosus* furnished.

Make for examination at the next and following exercises three gelatin plates from a sample of water furnished (unfiltered creek or well water), using for each culture the quantity designated by the instructor. The quantity will depend upon the condition of the water.

EXERCISE XXIII

A STUDY OF BACTERIA IN WATER

106. It is important to know something of the bacterial contents of water as it is found in wells and streams, and to compare the bacteria ordinarily found in water with those present in freshly drawn milk. It will be observed that the normal bacterial flora of water and of milk are quite different.

REFERENCES. Percy and G. C. Frankland, Micro-organisms in Water. Clark and Gage, 34th Annual Report Massachusetts State Board of Health. Jordan, The kinds of bacteria found in river water, The Journal of Hygiene, Vol. III, No. 1 (1903).

107. Work for this exercise. Carefully examine and describe the cultures made from the colonies on the milk plates in the last exercise.

Examine and describe the colonies on the plate cultures made from water. Determine the number of colonies and approximately the number of each kind of colony on the plate.

Examine microscopically the bacteria from one of each kind of colony and determine the genus.

Inoculate a tube of milk and one of gelatin from each of three different colonies, if there are as many. In later exercises examine these cultures and compare them with those made from colonies of milk bacteria.

Examine and describe the cultures of *B. prodigiosus*.

Inoculate groups of media A and B from a culture of *Ps. fluorescens liquefaciens* furnished.

EXERCISE XXIV

A STUDY OF CERTAIN PYOGENIC BACTERIA

108. There are a number of bacteria which are able to cause suppuration, but ordinarily the formation of pus is due to the presence of certain streptococci and micrococci. A number of bacilli, especially *B. coli communis* and *Ps. pyocyaneus*, are frequently found as the apparent cause of suppuration. As it is impossible to study more than a very few of these species, two of the most common and one of the more rarely encountered organisms in suppurating wounds and abscesses are chosen for special study.

REFERENCES. Chapters on pyogenic bacteria in text and reference books. Christman (recherches sur la suppuration), *Annals de l'Inst. Pasteur*, Vol. II (1888), p. 469. Lucet (in animals), *Ibid.*, Vol. VII (1893), p. 325. Von Lingelsheim (concerning streptococci), *Zeitschrift für Hygiene*, Bd. X (1892), S. 331. Moore, *Am. Vet. Review*, January, February, and March, 1900.

109. Work for this exercise. Inoculate a tube of each medium in Groups A and B from each of the cultures of *Streptococcus pyogenes* and *Micrococcus pyogenes aureus* which will be furnished.

Describe the cultures of *Ps. fluorescens liquefaciens* and examine the bouillon culture microscopically in a hanging-drop and in a stained preparation.

Examine the milk and gelatin cultures made from the colonies from milk and water plates.

Read carefully the chapter on pyogenic bacteria in the text-books.

Give in the notes a definition of each of the following terms : saprophytic, parasitic, pathogenic, and pyogenic bacteria. See text-books.

EXERCISE XXV

PYOGENIC BACTERIA (*continued*)

110. Work for this exercise. Examine and carefully describe the cultures made in Exercise XXIV. Note especially the growth on the agar, gelatin, and potato, and in the tubes of the bouillon containing the sugars. In describing the color use color charts which are in the laboratory.

Examine microscopically in (1) hanging-drop and (2) stained cover-glass preparations the bacteria from the bouillon and agar cultures.

Measure a few of the bacteria in the stained preparations from the agar cultures, and make a drawing of them, magnified 1000 diameters.

Inoculate for Exercise XXVI a tube of each medium in Groups A and B from a culture (furnished) of *Ps.* (*Bacillus*) *pyocyaneus*.

For suggestions in studying cultures and microscopic preparations of bacteria, see Exercises VI and XII.

Include in the notes the names of the different forms of *Micrococcus pyogenes* and a classification of streptococci.

EXERCISE XXVI

PSEUDOMONAS PYOCYANEUS

111. *Pseudomonas pyocyaneus*, commonly known as the bacillus of green pus, blue pus, or blue-green pus, is quite widely distributed in nature. While ordinarily it has been considered of little pathogenic importance, it is known to possess at times, and under certain conditions, marked infecting powers. This organism has been called the honey bacillus, on account of the peculiar odor emitted from its cultures. It is to be differentiated from *Ps. fluorescens liquefaciens* and its varieties which frequently appear in water.

REFERENCES. Chapters on this organism in text-books. Barker, The clinical symptoms, etc., The Jour. of the Am. Med. Asso., July 31, 1897. Lartigau, Study of pathogenesis, Jour. of Exp. Med., 1898, p. 595. Jordan, Pigments produced by, *Ibid.*, 1899, p. 627. Růzicka, Arch. für Hygiene, Bd. XXXIV, S. 149, and Bd. XXXVII, S. 1.

112. Work for this exercise. Examine very carefully and describe fully the cultures of *Ps. pyocyaneus* made during the last exercise.

Make and examine a hanging-drop and a stained cover-glass preparation from each of the bouillon and agar cultures. Describe the appearance of the bacteria in each.

Measure and make a drawing of a few organisms in the preparation from the agar culture. Magnify 500 diameters.

Reëxamine the cultures of the streptococcus and the micrococcus studied in the last exercise and note all appreciable changes which have taken place.

Inoculate a tube of each of the media in Groups A and D from a culture of *B. coli communis* (furnished) for study at the next exercise.

EXERCISE XXVII

BACILLUS COLI COMMUNIS

113. Of the bacteria normally present on the mucous membranes of the animal body the colon group is, on account of its close morphological relationship to the bacilli of typhoid fever and hog cholera, of more than ordinary interest. There are varieties of this organism which approximate very closely in their biochemic properties as well as in their morphology to the typhoid and also to the hog-cholera bacilli. It is important that this existing variation be recognized and that the list of properties which characterize *B. coli communis* should be clearly determined. The differentiation of the colon and typhoid bacilli as they exist in nature is one of the difficult problems in practical bacteriological work. The culture assigned approaches very closely to the typical species.

REFERENCES. Chapters on this organism in the text-books. T. Smith, The Am. Jour. of Med. Sci., September, 1896. Adelaide W. Peckham, Jour. of Exp. Med., Vol. II (1897), p. 549. Adami, *Ibid.*, Vol. IV (1899), p. 349. Gage and Phelps, Report Am. Pub. Health Asso., 1902, p. 402. Moore and Wright, Am. Med., Vol. III (1902), p. 504.

114. Work for this exercise. Describe the appearance of each of the cultures of *B. coli communis* made in Exercise XXVI.

Examine the bacteria in a hanging-drop preparation from the bouillon and glucose bouillon cultures.

Make and stain with carbol fuchsin a cover-glass preparation from the agar culture. Measure a few of the bacilli and record their size in the notes.

Note especially the quantity of gas formed in each of the fermentation tubes. These cultures should be kept until the

next exercise, when they should be examined again. If the gas formation is then completed, determine the quantity in each tube and the ratio of CO_2 to H.

Make two gelatin plates from the bouillon culture. In making these plates use a tube of sterilized distilled water for the first dilution.

Inoculate Group D of media with the paracolon bacillus from a culture furnished.

Test the culture in sugar-free bouillon for the presence of indol if it is at least 72 hours old. Read the chapter on this organism in the text-books.

115. The indol (cholera-red) test. Add 1 cc. of a .01% solution (fresh) of potassium nitrite and a few drops of concentrated sulphuric acid to the culture in sugar-free bouillon. A pinkish color indicates the presence of indol. In an old (3 to 5 day) culture the reaction is usually stronger than in a more recently made one.

If sugar-free bouillon is not at hand, a tube of *Dunham's solution* can be used instead with quite good results.

Ring method. When there is a small quantity of indol it can be detected more readily by the "ring method." Add 1 or 2 cc. of a 25% solution of H_2SO_4 , allowing it to run down on the inside of the tube containing the culture. Add 1 cc. of potassium nitrite. If indol is present, a pinkish ring will be observed between the layer of acid in the bottom of the tube and the culture above it.

116. Dunham's peptone solution. This is simply a solution of peptone and sodium chloride in distilled water. The formula is as follows:

Dried peptone	1 gram
Sodium chloride	0.5 gram
Distilled water	100 cc.

Dissolve the peptone and salt in the water, distribute it in the tubes (5 cc. each), and sterilize the same as bouillon.

EXERCISE XXVIII

BACILLUS COLI COMMUNIS AND THE PARACOLON

117. Work for this exercise. Reëxamine the cultures of *B. coli communis* and note any changes which have occurred in their appearance. Determine the gas formula in the fermentation tubes with the different sugars. Place the milk and litmus-milk cultures in the incubator and examine them later.

Examine carefully and describe the cultures of the paracolon bacillus. Examine microscopically at least one culture. Note especially its motility.

Examine and describe fully the colonies on the gelatin plates. Preserve the plates and examine them at the following exercises.

Examine microscopically, in a stained preparation, the bacteria from a colony on the gelatin plate. Preserve a preparation to accompany the notes.

Isolate *B. coli communis* from the intestine of an animal. The intestine will be furnished.

Inoculate with *B. cholerae suis*, for Exercise XXIX, a tube of each medium in Groups A and D, and similar tubes with *B. typhosus*, from the cultures furnished.

118. Isolating *B. coli communis* from the intestine. Carefully open the intestine by a longitudinal incision. Scrape away the contents, if any, from a small area of the mucous membrane. Take a loopful of the mucus from the surface of the mucous membrane and inoculate a large tube of liquefied gelatin with it. After shaking the tube carefully, inoculate a second tube with 2 loopfuls from the first, and a third with 3 loopfuls from the second. Pour the gelatin into Petri dishes and label them. These plates should be examined daily. The colonies of *B. coli communis* can be distinguished from others which may appear by their thin spreading growth, sharply defined but irregular borders, and their bluish appearance, especially with transmitted light. Compare with colonies on gelatin plates from a pure culture (Exercise XXVII).

EXERCISE XXIX

BACILLUS CHOLERÆ SUIS AND BACILLUS TYPHOSUS

119. The bacilli of typhoid fever and of hog cholera resemble each other very closely morphologically and in certain of their cultural characters and biochemic properties. Like *B. coli communis* each of these organisms has several varieties. Already several distinct varieties of the hog-cholera bacillus have been described.¹

Certain of the varieties of these species approach each other very closely, while others approach *B. coli communis* in their various manifestations. It is important, therefore, that the morphology and properties of each of these species should be carefully determined. The fact should be kept clearly in mind that while these two species and the colon bacillus resemble each other in certain directions, they are, so far as has yet been demonstrated, distinct species. The special methods of differentiation must be omitted from this elementary course. Read carefully the chapter on *B. typhosus* in the text-book.

REFERENCES. To hog cholera. Salmon, Special Report on Hog Cholera, Bureau of Animal Industry, U. S. Depart. of Agric., 1889. Smith, Bulletin No. 6, *Ibid.*, 1894. Moore, Report N. Y. State Commissioner of Agriculture, 1897. The Am. Vet. Review, March, 1898.

REFERENCES. To typhoid. Chapters on this organism in text-books. Eberth, Virchow's Archiv, Bd. 81, 1880. *Ibid.*, Bd. 83, 1881. Gaffky, Mittheilungen aus d. Kais. Gesundheitsamte, Vol. II, 1884, S. 372. Lösener, Arbeiten aus d. Kais. Gesundheitsamte, Vol. XI, 1895. Péré, Annales de l'Inst. Pasteur, Vol. VI, 1882, p. 512. Jordan, Medical News, September 28, 1895. Flexner,

¹ The hog-cholera group of bacteria, Bulletin No. 6, U. S. Bureau of Animal Industry, p. 9.

The Johns Hop. Hosp. Reports, Vol. V, p. 343. Smith, The Jour. of the Boston Soc. of Med. Sciences, June, 1898. Hiss, The Jour. of Exp. Med., Vol. II, 1887, p. 677.

120. Work for this exercise. Examine the plate cultures made from the intestine for the colon bacillus.

Determine the approximate number of colonies on each plate and note especially the number of colonies of *B. coli communis* and describe their appearance.

Inoculate a tube of agar, one of milk, and a fermentation tube of glucose bouillon from one of the colonies. Study these cultures in the next exercise and compare them with the notes on cultures of *B. coli communis* in these media.

Examine and carefully describe the cultures of *B. cholerae suis* and *B. typhosus*. Note especially the reaction of the cultures in the fermentation tubes. Examine the bouillon cultures microscopically in hanging-drop and in stained cover-glass preparations. Describe the appearance of the bacteria.

Make a series of 3 gelatin plate cultures from the bouillon culture of each organism.

EXERCISE XXX

BACILLUS CHOLERÆ SUIS AND BACILLUS TYPHOSUS

(continued)

121. Work for this exercise. Reëxamine all of the cultures of *B. choleraë suis* and *B. typhosus*. Note especially the condition of the fermentation tubes. Keep the milk and the litmus-milk cultures in the incubator for about 5 weeks and note any changes which may take place from week to week.

Examine and carefully describe the colonies on the gelatin plates.

Try the indol test (§ 115) with the culture in sugar-free bouillon.

Make and stain with alkaline methylene blue a few (3 or 4) cover-glass preparations from the organs (liver, spleen, kidney, or blood) of a rabbit which has died from the effects of the inoculation with hog-cholera bacilli. Note the number (few or many) of bacteria in the preparations and preserve one of them to accompany the notes. Make a drawing of a few bacilli.

Examine and complete the notes on the culture of *B. coli communis* and the paracolon bacillus. Compare them with the cultures of hog-cholera and typhoid bacteria.

122. Making cover-glass preparations from tissues. With a pair of fine forceps take up a bit of tissue from the freshly cut liver, spleen, or kidney, and rub it gently over the surface of a clean cover glass, care being taken that the film of tissue is thin. Allow this to dry in the air, after which pass the cover glass, film up, three times through the flame to fix the tissue to the glass. It can be stained the same as the cover-glass preparations from the cultures. When carbol fuchsin is used for staining, the preparation should be wet before applying. These are often spoken of as smear preparations.

In making these preparations from blood, hold a cover glass by the edge with a pair of dissecting forceps. With the platinum loop place a drop of blood on the cover glass near the forceps. Take a thick, square cover glass by the edge, rest it on the first above the drop of blood, hold it at an angle of about 20° from it, and draw it down over the first, thus spreading the blood in a very thin, even film over the surface. If the film is thick, the preparation should be rejected and another made.

EXERCISE XXXI

BACILLUS CHOLERÆ SUIS AND BACILLUS TYPHOSUS
(continued)

123. Work for this exercise. Reëxamine and complete the notes on all of the cultures except the milk and litmus milk. Carefully observe the reaction of all the liquid cultures.

Compare the colonies on the gelatin plates with those of *B. coli communis*.

Make a careful comparison, in tabulated form, of the morphology, including measurements, of the bacilli themselves and of the appearance of the growth in the different cultures of *B. coli communis* and the bacilli of hog cholera and typhoid fever. Add the cultural characters of the paracolon bacillus.

The cultures, excepting those in milk, can be rejected now, or, if desired, they may be kept for further study and comparison. Inoculate the media in Groups A and B with the bacillus of dysentery from a culture furnished.

EXERCISE XXXII

BACILLI OF DYSENTERY

124. A number of bacilli have been isolated from the intestine from cases of dysentery. The first of these organisms seems to have been described by Shiga, who isolated it from cases of dysentery in India. Since his work was published a number of bacilli very closely related to the one he described, if not identical with it, have been found in this country. In this exercise one or more of these organisms will be studied.

REFERENCES. Shiga, Centralblatt F. Bakt., Vol. XXIII, p. 599, Deutsche Med. Wochensch., Vol. XXVII, p. 741. Kruse, *Ibid.*, p. 370. Duval and Bassett, Am. Med., Vol. IV, p. 417. Gay, Univ. Penn. Med. Bulletin, Vol. XV, p. 307. Duval and Gay, *Ibid.*, Vol. XVI, 1903, p. 177. Flexner, *Ibid.*, Vol. XIV, p. 190. Park and Carey, Jour. Med. Research, Vol. IX, 1903, p. 180.

125. Work for this exercise. Study and carefully describe the cultures of dysentery bacteria made in the last exercise.

Examine the bacteria in the hanging-drop and in stained cover-glass preparations from the bouillon and gelatin cultures. Describe the morphology and make a drawing of a few bacilli, giving their size by actual measurement.

Compare carefully the cultural characters of this organism with those of hog-cholera, typhoid, and colon bacilli.

EXERCISE XXXIII

WIDAL SERUM TEST

126. This test depends upon the fact that when the blood serum of a person suffering with typhoid fever, or who has recently recovered from it, is added to a bouillon culture of the bacillus, the bacilli become less motile and soon agglutinate in small clumps. The dilutions used vary from equal parts of serum and culture to dilutions of 1 to 50,000. It is recommended that the stronger dilutions shall be used, i.e. those from 1:10 to 1:50. The test has proven to be of much diagnostic value in typhoid fever.

It has been found that a similar reaction will take place with certain other bacteria when they are brought in contact with the serum from animals suffering from the disease which they produce. Thus it has been shown that such a reaction occurs with hog-cholera bacilli and serum from affected or immunized animals.

On account of the diagnostic value of this reaction it is employed very extensively in many health departments for the diagnosis of typhoid fever.

REFERENCES. Black, Johns Hop. Hosp. Bulletin, December, 1896. Welch, The Jour. of the Am. Med. Asso., August 14, 1897. Johnston, N.Y. Med. Jour., October 31, 1896; Med. News, January 23, 1896. Biggs and Park, The Am. Jour. of the Med. Sci., March, 1897. Wesbrook and Wilson, The Phila. Med. Jour., March 26, 1898. Dawson, N. Y. Med. Jour., February 20, 1897 (concerning hog cholera). Cabot, Serum Diagnosis of Disease, 1899. Ruediger, The Jour. of Infect. Diseases, Vol. I, p. 236. See also recent text-books.

127. Work for this exercise. Take one loopful of a fresh bouillon culture of typhoid bacilli (which will be furnished) and place it on a cover glass, add one loopful of diluted blood

serum from a typhoid patient, or the blood of an immune guinea pig, and immediately make a hanging-drop preparation with a loopful of the mixture and examine. Note the effect on the motility of the bacilli and their aggregation into clumps. Specify the time elapsing before the agglutination appears and the time required for the complete clumping.

Make a similar examination of a culture to which 1/10 blood serum has been added.

Repeat the above test with the blood from animals affected with or immunized against hog cholera.

Examine a dried specimen of blood for this reaction. Add a few drops of bouillon or water to the drop of dried blood on a slide, and after it has become well mixed add a loopful of it to a similar quantity of a fresh bouillon culture and examine it immediately in a hanging drop.

Inoculate the media in Groups A and B with the culture furnished of *B. septicæmiæ hemorrhagicæ*, or *M. lanceolatus*, or both, as directed.

128. Securing blood for the widal test. (*a*) *Preparation of dried blood.* Prick the finger or lobe of the ear (if a lower animal, the shaved ear is a good place) sufficiently deep to procure a drop of blood. Place it on a slide by means of a platinum loop and allow it to dry.

(*b*) *Fresh blood.* Procure a drop of blood as in (*a*); add to it 10 drops of water on a glass slide or in a small test tube. Stir until the blood is dissolved. One loopful of this mixed with a similar quantity of the bouillon will give a dilution of 1 to 20.

(*c*) *Serum.* From a similar but deeper prick, or by drawing a few drops of blood from a vein with a hypodermic syringe, secure a few drops of blood. Place them in the bottom of a small, short, sterile tube and allow the serum to ooze out. This can often be helped by separating the blood from the tube by means of a sterile wire. If retained for any length of time before making the test, the serum must be kept in a

cool place. Experimentally, it is easily obtained by immunizing a guinea pig and then drawing the desired amount of blood from a vein.

Blood serum may be obtained by filling a small (capillary) glass tube with the fresh blood, sealing it, and allowing it to stand until the serum collects on the top, when the tube may be broken and the serum drawn off with a fine-pointed pipette.

EXERCISE XXXIV

BACTERIUM SEPTICÆMIÆ HEMORRHAGICÆ OR
MICROCOCCUS LANCEOLATUS

129. The first of these organisms is the cause of swine plague and a number of different diseases in animals, while the latter is the cause of lobar pneumonia in man.

The name *Bacillus septicæmiæ hemorrhagicæ* was given by Hüppe to the bacillus of swine plague (Smith). This bacterium (bacillus) is morphologically and in its cultural characters not distinguishable from the bacterium (bacillus) of rabbit septicæmia (Koch), of fowl cholera (Pasteur), and of *Schweineseuche* (Schütz). It is similar to a species of pathogenic bacteria found more or less frequently in the upper air passages of nearly all of the domesticated animals. It is very similar also to a pathogenic bacillus found in broncho pneumonia in cattle and an infectious pneumonia in sheep. These organisms are also known as the *Pasteurellose*, i.e. belonging to the genus *Pasteurella* of Trevison.

*Micrococcus lanceolatus*¹ is the specific organism of lobar pneumonia in man. It is found in the pneumonic lung tissue and also in the saliva of a certain number of healthy people. In many of its properties this organism resembles very closely the bacterium of swine plague. In studying the two species together there will be good opportunity of comparing them and detecting the differences and similarities existing between them.

REFERENCES. To swine plague. Smith, Report on swine plague, Bureau of Animal Industry, U. S. Depart. of Agric., 1891. Smith, Zeitschrift für Hygiene, Bd. X, 1891, S. 480. Smith and

¹ For the history and synonymy of this organism, see article by Professor Welch in the Johns Hopkins Hospital Bulletin, Vol. III, p. 125.

Moore, Bulletin No. 6, Bureau of Animal Industry, 1894. Moore, Report N.Y. State Com. of Agric., 1897. Nocard, Am. Vet. Review.

REFERENCES. To *M. lanceolatus*. Chapters on *Micrococcus lanceolatus* (*diplococcus pneumoniae*) in text-books. Welch, Johns Hop. Hosp. Bulletin, Vol. III, 1892, p. 125.

130. Work for this exercise. Carefully examine and describe the cultures made in Exercise XXXIII.

Examine the agar and bouillon cultures microscopically in both the living condition and in stained cover-glass preparations.

Describe the appearance of the bacteria and make a drawing of a few of them from one preparation magnified 1000 diameters.

Preserve a preparation to accompany notes.

If there is any growth in the gelatin tube, make a series of 3 gelatin plates from the bouillon culture.

Measure a few of the bacteria with the filar micrometer and record the measurements.

Inoculate a tube of glycerin agar, egg medium, and glycerin bouillon from a culture of avian tubercle bacteria for study in Exercise XXXVI.

EXERCISE XXXV

BACTERIUM SEPTICÆMIÆ HEMORRHAGICÆ OR
MICROCOCCUS LANCEOLATUS (*continued*)

131. Work for this exercise. Reëxamine all the cultures of these bacteria, paying special attention to the reactions of the liquid cultures.

Make the indol test with the cultures in sugar-free bouillon.

Make, stain, and examine a cover-glass preparation from an organ and the blood of a rabbit which has died from the inoculation with swine-plague bacteria or with *Micrococcus lanceolatus* (the rabbit will be furnished by the instructor). Stain the preparations with an aqueous solution of fuchsin. Study the bacteria in these preparations and carefully compare the two. Indicate in the notes the differences, if any are found.

Give in the notes a list of characters and cultural properties of *Bact. septicæmiæ hemorrhagicæ* and of *M. lanceolatus* that are of differential value. In what properties do they differ from *B. cholerae suis* and *B. typhosus*.

Keep the cultures until the next exercise and compare them again, after which they may be rejected.

EXERCISE XXXVI

BACTERIUM TUBERCULOSIS

132. The tubercle bacterium does not grow readily on the ordinary media. For its cultivation blood serum, glycerin agar, or bouillon containing from 5 to 7% glycerin is ordinarily used. Formerly it was with much difficulty that it was made to grow from lesions in tuberculous animals; but when a culture was once started it could, on the media mentioned above, and sometimes on agar, be cultivated in subcultures with comparative ease. More recently Dr. Theobald Smith has described a method which renders its cultivation from tuberculous lesions much easier (for details, see Appendix IV). It grows very slowly and it is necessary that the temperature should be kept, without variation, at about 37° C. The avian variety grows much more readily on glycerin agar, egg medium, serum, and in glycerin bouillon. On account of these difficulties it is not practicable, in a general course, to cultivate this organism, but cultures on solid and liquid media will be furnished by the instructor for examination. It is important, however, to be able to recognize this organism in tissues and sputum, and consequently the following additional exercise in staining and studying it is given.

REFERENCES. Chapters on this organism in text-books. Smith, *Jour. of Exp. Med.*, 1898, p. 451. Moore, *Med. News*, May 14, 1892 (methods of staining). Nuttall, *Johns Hop. Hosp. Bulletin*, 1891, Vol. II, p. 67. Dorset, *Report Am. Public Health Asso.*, Vol. XXIV, p. 157.

133. Work for this exercise. Examine and carefully describe the appearance of the cultures of the tubercle bacterium (human or bovine variety) on glycerin agar and in glycerin bouillon furnished.

Make 2 cover-glass preparations from the cultures furnished for that purpose and stain them with carbol fuchsin (§ 100).

Make 4 cover-glass preparations from tuberculous sputum and stain for tubercle bacteria. It is often desirable to counterstain the specimens from sputa. Stain 2 of them by Gabbett's method and 2 with carbol fuchsin, and decolorize without counterstaining. Make a few (2 or 3) cover-glass preparations from the liver or spleen of a guinea pig which has died from tuberculosis, and stain them for tubercle bacteria. Stain one with carbol fuchsin and decolorize with sulphuric acid, and stain one by Gabbett's method.

Examine the cultures of avian tubercle bacteria and describe their appearance. Stain and examine a few preparations from one of the cultures.

Indicate in the notes the essential differences between human, bovine, and avian tubercle bacteria respecting (1) morphology, (2) cultural properties, and (3) pathogenesis.

Measure the tubercle bacteria in one of the preparations and make a drawing showing a few of them magnified 1000 diameters.

134. Making cover-glass preparations from sputum. Select the little yellowish-colored masses, if present, remove them by means of the fine forceps or platinum loop, and spread them on the cover glass in a thin layer. If the sputum is homogeneous, make the preparations the same as from cultures, using a small loopful of the liquid. If the sputum is viscid, it is necessary to use the forceps to spread the film on the cover glass. When dry, the films are fixed by passing the preparations through the flame, after which they are ready to be stained.

Instead of using cover glasses, it is the practice in some laboratories to spread the sputum in a thin film over the central part of a slide; dry, fix, and stain as with the cover glasses. The water is dried off by using filter or blotting paper, and the preparation examined without a cover glass. The method is said to be easier and quicker than the other, and the cleaning of cover glasses is saved.

135. Gabbett's method of staining tubercle bacteria.**1. The stain (carbol fuchsin) :**

Fuchsin	1 gram
Absolute alcohol	10 cc.
5 % carbolic acid	100 cc.

2. The decolorizer and counter stain :

Methylene-blue powder	2 grams
10 % sulphuric acid	100 cc.

Stain the preparation with the first solution as described (§ 100), then rinse in water and stain 1 minute with the second solution, which decolorizes and counterstains at the same time, and again rinse in water. If the film has a bluish tint, it is ready for examination ; if not, it should be stained a little longer in the second solution. In these preparations the tubercle bacteria should appear as slender, more or less curved, rod-shaped bodies of a deep reddish color, while the surrounding tissue and other bacteria present are stained a more or less intense blue.

Sudan III is reported by Dorset to be a very good differential stain for this organism. A saturated solution in 80% alcohol is used. It is reported to be effective in differentiating the tubercle organism from that of leprosy and from the smegma bacillus.

EXERCISE XXXVII

BACTERIUM MALLEI

136. This organism grows most characteristically on potato and somewhat feebly in the other media heretofore used. It develops readily on acid agar and in acid glycerin agar and acid glycerin bouillon. For this reason it is not inoculated into all of the media. In diagnosing glanders it is customary to inoculate guinea pigs with the suspected material (see Appendix III). From the lesions in these animals, if the disease develops, pure cultures can usually be obtained. It can be identified by its morphologic and cultural characters.

REFERENCES. Chapters on *Bacterium mallei* in text-books. Smith, The Jour. of Comp. Med. and Vet. Archives, March, 1890. De Schweinitz and Dorset, Jour. of the Am. Chem. Soc., Vol. XVII, 1898. Finkelstein, Centralb. f. Bakteriologie u. Parasitenkunde, Bd. XI, 1892, S. 433. Frothingham, Proceedings Am. Vet. Med. Asso., 1901, p. 360 (Straus' method of diagnosing glanders). See recent text-books.

137. Work for this exercise. Inoculate a tube of potato, one of agar, one of acid agar, one of acid glycerin agar, one of glucose agar, one of bouillon, and one of acid glycerin bouillon from a culture furnished. (The special media here introduced will be furnished by the instructor.)

Stain cover-glass preparations (furnished) made from the lesions in guinea pigs which were inoculated with this organism. Stain one with alkaline methylene blue and one with carbol fuchsin. Note especially the morphology and the extent to which the organisms take the stain.

Reëxamine the cultures of avian tubercle and complete the notes on the same.

EXERCISE XXXVIII

BACTERIUM MALLEI (*continued*)

138. Work for this exercise. Examine and carefully describe all the cultures of *Bacterium mallei*.

Make 2 cover-glass preparations from the acid agar and from the bouillon cultures, and stain one of each with alkaline methylene blue and one with carbol fuchsin. Describe the bacteria and make a drawing of a few of them. Preserve 1 preparation. Keep the cultures and reëxamine them at each of the 3 following exercises. Note especially the character and color of the growth on the potato and in the acid glycerin bouillon.

Examine carefully the lesions produced by the inoculation of *Bacterium mallei* in a male guinea pig (Straus' method of diagnosing glanders).

Inoculate by Liborius' method (§ 141) 2 tubes of liquid agar, one sugar free, the other containing glucose, 2 fermentation tubes, one sugar free, the other containing 1% glucose bouillon from a culture of an anaërobic bacillus, the bacillus of malignant œdema or of symptomatic anthrax is preferable (furnished), and place the inoculated tubes in the incubator.

EXERCISE XXXIX

CULTURES OF ANAËROBIC BACTERIA

139. Certain bacteria will not grow in the presence of oxygen (atmosphere), and consequently they must be cultivated in a medium from which the air has been expelled, or in the presence of some natural gas such as hydrogen. While certain bacteria, like those of symptomatic anthrax, tetanus, and malignant oedema, require the absence of oxygen, others, like *Bacillus subtilis*, will not multiply without it. There are, however, a large number of bacteria which are able to multiply independently of the presence or absence of this element. In reference to oxygen requirements bacteria are grouped as follows :

Obligative aërobic bacteria require oxygen.

Obligative anaërobic bacteria require the absence of oxygen.

Facultative aërobic bacteria grow best in the absence of oxygen, but will grow in the presence of air.

Facultative anaërobic bacteria grow best in the presence of oxygen, but will grow in its absence.

There are several methods of cultivating anaërobic bacteria, but as a rule they are difficult and cannot be easily handled in an elementary course. Two of the simpler processes, however, will be tried.

REFERENCES. See text-books on bacteriology. Hunziker, Jour. of Applied Microscopy, Vol. V, No. 3. Gould, Annals of Surgery, October, 1903.

140. Work for this exercise. Examine and carefully describe the appearance of the anaërobic cultures made in Exercise XXXVIII.

With the wire loop remove one of the colonies from the depth of the agar culture and examine it microscopically (1) in a hanging-drop preparation and (2) in a stained cover-glass

preparation. Stain with carbol fuchsin. Examine microscopically in similar preparations the bacteria from one of the fermentation tubes; describe their appearance in each preparation and make a drawing of a few of them.

Note the appearance of the cultures inoculated for the study of the gas production.

Inoculate (Liborius' method) 2 tubes of agar, one sugar free, the other containing 1% glucose, and 2 fermentation tubes, one containing sugar-free bouillon, the other 1% glucose bouillon from a culture of *B. tetani* furnished.

Read carefully in the text-books the methods for cultivating anaërobic bacteria.

141. Culture by Liborius' method. Liquefy 2 tubes of agar and carefully pour them together. After this, boil the medium for at least 5 minutes to expel the air, cool it down to a temperature of 40° C., and then inoculate it from the culture of an anaërobic organism furnished, after which cool the medium rapidly by standing it in cold water until it is set. In inoculating the tube insert the loop nearly to the bottom and stir very gently. In making the inoculations care must be taken not to introduce air by shaking the liquid medium. Place the culture in the incubator.

142. The fermentation tubes for cultivating anaërobic bacteria. If these tubes of bouillon have been properly sterilized, the closed branch is practically free from atmosphere. The obligatory anaërobe will grow in the closed branch only, while the facultative anaërobe will grow in both the open and closed parts. If the organism is a gas producer, the gas will force the cloudy liquid from the closed bulb into the open one, clouding the otherwise clear liquid. To avoid the possibility of error in interpreting these growths it is well to inoculate a tube containing sugar-free bouillon, in which case the liquid in the open bulb should remain clear, as gas will not be formed.

These tubes are of equal value in testing obligatory and facultative anaërobic organisms.

EXERCISE XL

BACILLUS TETANI

143. The bacilli of tetanus or their spores occur in nature as common inhabitants of the soil — at least they are found in the soil in certain localities. They are believed to be more numerous in certain places where manure has been thrown in abundance. *Bacillus tetani* is anaërobic and consequently must be cultivated according to methods necessary for such bacteria (§§ 141, 142). In its effect upon the animal body it remains at the point of inoculation, the disease being produced by the toxin elaborated by the bacilli.

REFERENCES. See text-books. Kitasato, Zeit. f. Hygiene, Bd. X., S. 267. Wesbrook, Jour. Path. and Bact., Vol. III, p. 70. Kanthack (morphology), *Ibid.*, Vol. IV, p. 452. Vaillard and Rouget (etiology), Ann. de l'Inst. Pasteur, T. VII, p. 755.

144. Work for this exercise. Carefully examine the 2 cultures of tetanus bacilli made in the last exercise and describe their appearance.

Make 2 cover-glass preparations from the liquid culture and stain them with carbol fuchsin. Examine them microscopically and describe their appearance. Make a drawing of a few bacilli magnified 1000 diameters. Keep these cultures until the next exercise, when they should be reëxamined, sterilized, and rejected.

Inoculate a tube of each medium in Groups A and B with *Bacterium anthracis* from a culture furnished for study at the next exercise.

145. Method of isolating tetanus bacilli. Tetanus bacilli rarely extend beyond the place of inoculation into the body of the infected individual (man or lower animal). In the local lesion there are almost always other bacteria, so that

cultures made directly from the lesions are usually impure. I have found that very often pure cultures may be obtained by inoculating a guinea pig with the pus or exudate from the local lesion and making cultures from the local lesions in the guinea pig, the juices of the body having destroyed the saprophytic bacteria which were present in the first material.

Kitasato has recommended a procedure which is reported to be fairly successful. It is to inoculate a tube of agar with tissue from the local lesion, and after it has grown for from 24 to 48 hours at a temperature of 37°C . heat the tube to 80°C ., which kills all the other bacteria, but does not destroy the tetanus spores. From this culture anaërobic cultures are prepared.

EXERCISE XLI

BACTERIUM ANTHRACIS

146. Anthrax is a disease affecting cattle and man. *Bacterium anthracis* is interesting because of its spores, which are very resistant to disinfectants. Because of its striking morphology it can be differentiated microscopically in fresh tissues. In tissues some hours after death there is a putrefactive organism that resembles it morphologically. *Bact. anthracis* is readily diagnosed in cultures.

147. Work for this exercise. Examine and describe each of the cultures of this organism made during the last exercise.

Examine microscopically the bouillon and agar cultures in both hanging-drop and stained cover-glass preparations.

Measure a few of the bacteria in a stained preparation and make a drawing of them magnified 1000 diameters.

Make a series of 2 agar plates from the bouillon culture.

Examine sections of animal tissue containing anthrax bacteria. Make and examine a few cover-glass preparations from the liver of an animal (guinea pig or rabbit) which has just died of anthrax. (This will be furnished by the instructor.)

In notes state whether or not a microscopic examination of tissues is sufficient to make a diagnosis of anthrax.

EXERCISE XLII

BACTERIUM ANTHRACIS (*continued*)

148. Work for this exercise. Reëxamine all of the cultures of *Bacterium anthracis* and describe any changes in their appearance which may have taken place.

Examine the agar culture for spores in a hanging-drop preparation and in a stained cover-glass preparation. Describe the appearance of the bacteria and spores in a preparation from each.

Study and describe the appearance of the colonies on the agar plates. Make an outline drawing of a few of the surface and deep colonies.

Reject all cultures except the agar plates, which may be kept until the next exercise for further observation before rejecting. (These cultures should be put in charge of the instructor, who will see that the spores are destroyed before the tubes are cleaned.)

Inoculate a tube of each medium in Groups A and B and also a tube of Loeffler's blood serum and glycerin agar with *Bacterium diphtheriæ* from a culture furnished for study at the next exercise.

REFERENCES. Chapters on anthrax in recent editions of textbooks. Chester, Report Delaware College Agric., Exp. Station, July, 1895. Moore, Report N. Y. State Com. of Agr., 1897. Emmerich and Saida, Centralb. f. Bakter. u. Parasitenkunde, Bd. XXVII, S. 776. Bongert, *Ibid.*, Bd. XXXIV, S. 497. Preisz, *Ibid.*, Bd. XXXV, S. 280.

EXERCISE XLIII

BACTERIUM DIPHTHERIÆ

149. The bacterium of diphtheria is often called the Klebs-Loeffler bacillus. It is the specific cause of diphtheria in man ; but it is not, so far as known, the cause of diphtheria in pigeons and poultry. It is found in the throats of people suffering with diphtheria, and often in the throats and noses of those who have been exposed to it. These are designated as "germ cases." Ordinarily it is not found elsewhere in the body, although it is occasionally discovered in the internal organs and blood. It usually remains in the throat for some days after its lesions have disappeared. Its appearance in the throat lesions is made use of in diagnosing the disease. For this reason it is especially important that its morphology, as well as its cultural characters, should be carefully determined. Although this organism grows on nearly all of the media commonly used, its development is more rapid and its growth more characteristic on Loeffler's blood serum. The bacterium of diphtheria seems to be modified in its morphology in growing on different media more than any of the other pathogenic bacteria. Particular attention should be given to its morphology and staining properties.

REFERENCES. Chapters on diphtheria in recent editions of text-books. Loeffler, Mitth. aus d. Kais. Gesundheitsamte, Bd. II. Biggs, Park, and Beebe, Scientific Bulletin No. 1, Health Dept. City of New York, 1895. Wesbrook (varieties), Jour. Boston Soc. Med. Sciences, Vol. IV, p. 75. Report Am. Pub. Health Asso., 1899, p. 546. Hill (branching forms), *Ibid.*, p. 554. Bergey (pseudo-diphtheria), Publications of the University of Pennsylvania, new series, No. 4, 1898. Smith (toxin), Trans. of the Asso. of Am. Phys., 1896. (Current medical literature contains many articles on this subject.) Hill, Report Boston Board of Health, 1901.

150. Work for this exercise. Examine and describe the cultures made in Exercise XLII.

Examine the serum, glycerin agar, and bouillon cultures microscopically in stained cover-glass preparations. Stain with alkaline methylene blue. The preparation should be stained for fully 5 minutes and decolorized for a few seconds with alcohol. Examine the bouillon culture in a hanging-drop preparation.

Examine carefully a fresh culture made directly from a diphtheritic throat, including stained cover-glass preparations.¹ Stain with alkaline methylene blue and by Neisser's method. (It is not always possible to obtain these cultures at this particular time, in which case the examination will be postponed until they are available.)

151. Neisser's method of staining diphtheria bacteria. Neisser has recently recommended the following method of staining, in which 2 solutions are employed, viz. :

(a) One gram of methylene blue (Grübler's) is dissolved in 20 cc. of 96% alcohol, which is then mixed with 950 cc. of distilled water and 50 cc. of glacial acetic acid.

(b) Two grams of vesuvium are dissolved in 1 litre of boiling distilled water and filtered.

The cover-glass preparations are stained in (a) for from 1 to 3 seconds, washed in water, and then stained in (b) for from 3 to 5 seconds, again washed in water, dried, and mounted. Stained in this manner the bacilli are brown, and contain 2, or rarely 3, but never more, blue corpuscles. The corpuscles are oval, not round, in shape, and their diameter appears greater than that of the bacilli in which they are situated.

¹ Clinically, *Bacterium diphtheriæ* is to be differentiated from the pseudo-diphtheriæ organism and from a bacillus which has been found in decayed teeth, and which is said to resemble very closely in its morphology the Klebs-Loeffler bacillus. It is also to be distinguished from the *Xerosis bacillus* isolated by Neisser. For detailed descriptions of these organisms, see text-books.

EXERCISE XLIV

BACTERIUM DIPHTHERIÆ (*continued*)

152. Work for this exercise. Examine microscopically, in stained cover-glass preparations, the bacteria from the glycerin agar and Loeffler's blood-serum cultures. Stain with alkaline methylene blue and note especially the way the bacteria stain. Stain a few preparations after Neisser's method (the staining solutions will be furnished) and compare with the methylene-blue stain.

Note with special care the morphology of the bacteria and make a drawing of a few of them. Compare the preparations with those made from the same cultures in previous exercise and note any differences in the morphology of the bacteria.

Examine very carefully a guinea pig (furnished) which has died from the effect of inoculation with diphtheria organisms.

Expectorate into a watch glass which has been wiped with a cloth moistened in a 5% solution of carbolic acid. From this sputum inoculate a tube of bouillon and one of slant agar, and make a series of 2 agar and one of 2 gelatin plate cultures. Use a small loopful of sputum for each tube culture and the same for the first tube in the plate series.

EXERCISE XLV

THE BACTERIA OF THE MOUTH

153. In studying cultures from the throats of diphtheritic individuals one encounters many variations in the species of bacteria other than those of diphtheria which are present. The same condition holds true with the microscopic examination of sputum for the tubercle bacteria. The fact has been determined that the organism of lobar pneumonia is often found in the human saliva, and, furthermore, the bacterium of swine plague (*Bacterium septicæmiæ hemorrhagicæ*) is often in the upper air passages of a large percentage of healthy swine, and a like organism is found in cattle, cats, and dogs. In order, however, to isolate them, it is usually necessary to resort to rabbit inoculation.

Much attention has been given to the study of the bacteria of the mouth, and it seems desirable that a few examinations should be made for the purpose of learning something definite concerning the variety of species which are normal inhabitants of, and which seem to be somewhat localized in, the oral cavity, and consequently which may be encountered in seeking for pathogenic forms. In addition to those forms which seem to be more or less localized on the mucosa of the mouth, there is usually present in the oral cavity a large and changing variety of bacteria which have been introduced with the food.

REFERENCES. Vicentini, Bacteria of the Sputa, London, 1897. Miller, Die Mikroorganismen des Mundhöhle, Leipsic, 1889. David, Les Microbes de la Bouche, Paris, 1890.

154. Work for this exercise. Examine carefully and describe fully the cultures made from sputum at the last exercise.

Make a hanging-drop preparation from one of each of the different kinds of colonies and describe the appearance of the

organism. Note the name of the genus to which each colony belongs, together with the approximate number of colonies of each.

Make one or more cover-glass preparations from the mouth and stain with alkaline methylene blue. Note carefully the varieties of bacteria they contain.

Inoculate from the unnamed cultures furnished such media as the requirements of the next exercise demand.

155. Making cover-glass preparations from the mouth. These can be made from the sputum, expectorated in a watch glass, or from the scrapings from the tongue, gums, pharynx, or from the base of the teeth. If any of the latter sources is chosen, the part from which the material is to be taken should be scraped carefully with a sterile (flamed) platinum loop or with the blunt point of a scalpel or other stiff instrument. The scrapings are spread on cover glasses the same as the sputum.

EXERCISE XLVI

IDENTIFYING BACTERIA FROM CULTURES

156. The two cultures of bacteria assigned for identification belong to species already studied, and the student should identify the species of bacteria in them. To do this such media should be inoculated and such microscopic examinations made as he thinks necessary. The notes should contain a complete record of the work and the reasons for the identifications made. This exercise affords a good opportunity to begin the use of manuals and text-books in identifying species.

157. Work for this exercise. Identify the bacteria in the cultures assigned at the last exercise. Use any method which seems to be necessary. In the laboratory notes give reasons for the procedure adopted.

Reëxamine and reject the cultures of *Bact. diphtheriæ*.

EXERCISE XLVII

ISOLATING AND IDENTIFYING BACTERIA FROM
ANIMAL TISSUES

158. In making a bacteriologic investigation into the cause of death in an animal or man it is necessary to make cultures from the various organs and the blood to find whether or not there are any pathogenic or other bacteria present. This necessitates a knowledge of making cultures from animal tissues. In this exercise an experimental animal (rabbit or guinea pig) which has died from some bacterial disease will be provided. The purpose of this examination is to find out what that disease is. To save animals, each student will make cultures from but one organ. From time to time during the course opportunity will be afforded for making cultures from variously diseased animal tissues.¹ Each student will be given opportunity to inoculate one or more animals some time during the course.

159. Work for this exercise. The experimental animal furnished will be tied out on a post-mortem tray and the viscera exposed. (Directions for the post-mortem examination will be given in the course in pathology.)

Inoculate a tube of bouillon, one of agar, and a fermentation tube of glucose bouillon from either the liver, spleen, or kidney. (In an actual investigation of an unknown disease, cultures should be made from all of the organs, blood, and lymphatic glands.)

Make a series of 3 agar plate cultures from the same organ.

Make and examine 2 cover-glass preparations from the organ from which the cultures were made. Stain one with alkaline methylene blue and one with carbol fuchsin. (It is

¹ For methods of inoculating animals for purposes of diagnosis, see Appendix III.

sometimes necessary to fix pieces of the tissue in alcohol or in some other fixing fluid for sectioning and staining, preparatory to studying them.)

Preserve one of the cover-glass preparations to accompany the notes.

160. Making cultures from animal tissues. Heat a platinum spatula to a white heat in a gas flame and scorch the surface of the organ. Flame a pair of fine forceps, tear an opening through the scorched surface, and crush a bit of tissue underneath it. With the platinum loop take up a loopful of the crushed tissue, with which inoculate the media. It is also desirable to inoculate a tube of slant agar with the needle by drawing it over the surface of the medium after charging it with tissue. In making plate cultures use a loopful of the crushed tissue for the first tube. The quantity of the tissue necessary to give a desired number of colonies cannot be anticipated, although experience in working with different organisms in animals renders one able to approximate the amount required.

EXERCISE XLVIII

ISOLATING AND IDENTIFYING BACTERIA FROM
ANIMAL TISSUES (*continued*)

161. Work for this exercise. Examine and describe all of the cultures made from the animal tissues.

Examine the bouillon and agar cultures microscopically both in the fresh condition and in stained cover-glass preparations.

If the species cannot be determined from these cultures and examinations, make such other cultures from these as may be necessary to enable one to do so.

After the species are identified, state in the notes the facts upon which the identification is made.

EXERCISE XLIX

THE EXAMINATION OF SECTIONS OF TISSUE
CONTAINING BACTERIA

162. The preparation of tissues for sectioning and the study of the tissue changes more properly belong to the course in pathology. It is important, however, that one should be able to distinguish bacteria in the lesions which they produce. For this reason an exercise is devoted to the study of bacteria in sections of tissues already stained and mounted. These include the various pneumonias, tuberculosis, anthrax, hog cholera, typhoid, septicæmia, etc.

163. Work for this exercise. Examine the sections furnished for bacteria and note especially their distribution in the tissues. Make drawings of a few of the bacteria from each preparation.

Compare the bacteria in the sections with the cover-glass preparations which have been made from cultures of the same species, and note any differences in their appearance which may be detected.

Examine all cultures for identification in previous exercises.

EXERCISE L

BACTERIOLOGIC EXAMINATION OF PUS AND EXUDATES

164. It is often very desirable for diagnostic purposes to make a bacteriologic examination of the pus from abscesses and the mucopurulent discharges or exudates from mucous or serous membranes.

Several diseases can be diagnosed in this way. It is often necessary to make cultures and it is always advisable to do so whenever the material is in a suitable condition. Among the specific diseases for which such an examination is especially valuable are actinomycosis, gonorrhea, diphtheria, and tuberculosis. Further, it is often desirable to determine the genera of the bacteria in the numerous abscesses and suppurating wounds encountered in both man and the lower animals. Such examinations of the more desirable cases will be made from time to time as they become available. In this exercise such cover-glass preparations will be examined as have been accumulated for this purpose.

165. Work for this exercise. Examine the pus in the fresh condition and note its composition, leucocytes, red blood corpuscles, fungi (actinomycosis), etc.

Make cover-glass preparations and stain one or more of them with carbol fuchsin and one with alkaline methylene blue and examine. Note the cellular tissue elements present and describe the bacteria found. If the pus is from a case suspected to be of a specific nature, stain and examine for the corresponding organism.

If actinomycosis, the ray fungus may be seen better in the fresh preparation. Add a drop of a 10% solution of caustic potash to a loopful of pus on the slide and cover it with a cover glass and examine.

If gonorrheal discharge, stain the cover-glass preparations with an alcoholic solution of eosin and alkaline methylene blue, or with carbol fuchsin. Note the appearance of the cocci both within and outside of the pus cells.

If from supposed tuberculosis, stain for that organism.

If from diphtheria, stain for that organism and note the morphology of the bacteria.

If from the pus of an abscess, stain for pyogenic bacteria.

166. Making cover-glass preparations from pus. Spread as thin a film of the pus as possible on the cover glass. This can be readily done by drawing the edge of a square cover glass over the surface of another cover glass on which a bit of the pus has been placed. See method for making cover-glass preparations from blood (§ 122).

EXERCISE LI

A BACTERIOLOGIC EXAMINATION OF THE SKIN FOR
MICROCOCCUS EPIDERMIDIS ALBUS AND
OTHER BACTERIA

167. There is liable to be on or in the skin a number of bacteria which resist the ordinary methods of cleansing, owing to their being deeply seated in the epidermis. The most important among these is *M. (Staph.) epidermidis albus*. These organisms often infect wounds in surgical operations. An abrasion of the skin with a sterile instrument may be followed by the infection of the wound with this or other species of bacteria which were on or in the skin itself. The work of this exercise is to demonstrate the presence of these organisms on the skin of supposedly sterilized hands.

REFERENCES. Dennis' System of Surgery, Vol. I, p. 249. This chapter, written by Professor Welch, contains a summary of the present knowledge of the bacteria of the skin, with references to original articles.

168. Work for this exercise. Wash the hands thoroughly with soap and water, using a sterilized brush. Then wash them in a solution of 1 to 1000 corrosive sublimate for 5 minutes, rinse thoroughly in boiled water, and wipe with a sterilized towel (furnished).

With a flamed and cooled scalpel scrape the epidermis over a small area about the finger nails, and with these scrapings inoculate a tube of bouillon and make a series of 2 agar plate cultures.

Make a similar series of cultures with the scrapings from the back or palm of the hand.

At the next exercise describe these cultures and examine the colonies microscopically to determine the genera of bacteria.

If a micrococcus which grows in clumps is found, inoculate a tube of agar with it, and at the following exercise examine and describe its appearance. Indicate in the notes the number of colonies of bacteria which developed in the plate cultures and the genera which appear in the bouillon culture.

EXERCISE LII

DETERMINING THE THERMAL DEATH POINT OF BACTERIA

169. It is important to know the minimum temperature which will kill bacteria, especially the pathogenic forms. The uses to which such knowledge can be put are numerous in practical sanitary medicine, disinfection, and pasteurization. For the various methods employed in making these determinations, see text-books and special articles on this subject. The method here given, and which can be followed by a full section of students, will give only approximate results. It should not vary, however, more than one degree from the actual thermal death point in moist heat of the organisms tested. In this exercise students may work in groups with satisfactory results and with the saving of much media.

170. Work for this exercise. Take 10 tubes of bouillon, place 8 of them in a wire basket, and stand it in the thermo-regulated water bath at 60° C. After 15 minutes remove the tubes and inoculate 4 of them from a culture of *B. subtilis* and 4 of them from a culture of *B. typhosus* or *B. cholerae suis* (the cultures will be furnished). In inoculating the tubes be sure not to touch the sides above the surface of the bouillon with the wire.

After the tubes are inoculated return them to the water bath adjusted at 60° C. The water should come just above the liquid in the tubes. Remove the tubes, one of each species, as follows: one in 5 minutes, one in 10 minutes, one in 15 minutes, and one in 20 minutes. Label and place them in the incubator.

Inoculate the other two tubes of bouillon, one from each of the cultures used, and place them in the incubator for controls.

At the next exercise examine the heated tubes and note which are clear and which contain a growth. If the tubes heated for 10 minutes or longer have a growth, repeat the experiment at 70° C. If this fails to destroy them, repeat at 80° C., and if necessary apply a still higher temperature.

Examine the cultures microscopically in all the fertile tubes to determine if they are pure.

Explain the cause for the difference in the thermal death point between these two organisms.

Examine the cultures made from the scrapings of the skin in the previous exercise.

EXERCISE LIII

DETERMINING THE EFFICIENCY OF DISINFECTANTS

171. The efficiency of the more commonly used disinfectants has been determined for most of the pathogenic bacteria, but new disinfectants are constantly being put upon the market, and before it is safe to use or recommend them, their efficiency should be determined. With many of the disinfectants, such as carbolic acid, corrosive sublimate, lime, and the mineral acids, much stronger solutions are commonly used than are actually necessary to kill the bacteria, owing to the fact that frequently it is necessary to allow for an indefinite waste due to the union of the disinfectant with other substances, usually organic, with which the bacteria are mixed. For the different methods of testing the efficiency of disinfectants, see text-books. A very simple process is given here.

It may be desirable for students to work in groups of two or more in order to economize in the number of tubes required. If possible, however, each student should make all of the tests.

REFERENCES. Young, Notes on Disinfectants and Disinfection, Augusta, 1898. Rideal, Disinfection and Disinfectants, London. Rosenau, Disinfection and Disinfectants. See also text-books.

172. Work for this exercise. Put 10 cc. of a 2% solution of carbolic acid, prepared from sterile distilled water, into each of 2 sterile test tubes. Add to one of these tubes, by means of a sterilized pipette, .25 cc. of a bouillon culture of *B. cholerae suis* or *B. typhosus*. To the other tube add a like quantity of a suspension in bouillon or sterile water of an agar culture of *B. subtilis* (furnished).

Inoculate a tube of bouillon containing fully 7 cc. with 6 loopfuls from each of these tubes after the expiration of the

following periods of time: 1 minute, 5 minutes, 10 minutes, and 30 minutes. In making these inoculations allow the loop to go to the bottom of the inoculated tube. Label each with the strength of the disinfectant and time of exposure and place it in the incubator. It should be noted that the adding of .25 cc. of culture diluted slightly the strength of the disinfectant.

Note at the next exercise the condition of each inoculated tube. From them the approximate strength of the disinfectant used and the time necessary to destroy the bacteria can be determined. When this is found the more exact strength and time can be determined by repeating the experiment with weaker dilutions or shorter exposures or both.

Examine cultures that were heated at the previous exercise.

EXERCISE LIV

PASTEURIZING AND STERILIZING MILK

173. Milk is pasteurized, in the present acceptance of the term, when all of the pathogenic bacteria which it may happen to contain (with the exception of the spores of anthrax) are destroyed, with the more important saprophytes. It is not necessarily sterile, although it sometimes is. The temperature should be from 60° to 68° C. and the time for heating 20 minutes.

In this exercise it is the purpose to study the effect of this process on the bacteria of milk and to compare its effect with that of sterilization.

In the generally accepted use of the term, milk is sterilized when it has been boiled. Milk, however, is a difficult substance to sterilize, so that it occasionally happens that milk which has been boiled for from 5 to 10 minutes still contains living organisms (spores).

In this exercise students may work in small groups.

174. Work for this exercise. From the fresh milk provided, make 2 agar plates, using 1 and 2 loopfuls, respectively, of the milk. Put 25 cc. in each of 6 large test tubes and set one in the incubator and leave one at the room temperature. Boil two of them for 30 minutes in a closed water bath, and pasteurize the remaining two by heating them in the water bath for 30 minutes at 65° C. It requires about 10 minutes for the milk in the tubes to reach the temperature of the water, leaving the milk exposed to the temperature of the water for 20 minutes. It should be cooled quickly by standing the tubes in cold water.

After the tubes are cooled, make 3 agar plates from one of the tubes treated by each process, using 1 loopful of milk for the first plate, 3 loopfuls for the second, and .25 cc. (measure with a graduated pipette) for the third. Place in the incubator

one of the tubes of milk treated by each process with the plate cultures, and leave the other tubes with a tube of the fresh milk at the room temperature.

At the next exercise note carefully the condition of the milk in each of the various tubes and also the number of colonies on the agar plates.

Examine the cultures made in Exercise LIII.

EXERCISE LV

THE QUANTITATIVE BACTERIOLOGIC EXAMINATION
OF WATER

175. This is to determine the number of bacteria in water. In preparing media for this purpose the directions given in the Journal of the American Public Health Association for January, 1898, p. 60, should be followed. The conditions of temperature and of media which favor growth differ for different species. Many bacteria found in water will not grow at the incubator temperature, while others which may be in it grow very slowly at the room temperature. To determine numbers it is better to grow the bacteria in gelatin plates at the temperature of the room. (In an actual examination a much larger number of plate cultures than can be managed here should be made.)

In this exercise students may work in small groups.

176. Work for this exercise. Make from the properly collected water 4 gelatin plates, using a definite quantity of water for each. To begin with, it may be safe to inoculate these tubes with 0.1, 0.25, 0.50, and 1.00 cc., respectively.

To determine if there are gas-producing bacteria, and the approximate number of these if any, inoculate 10 fermentation tubes with 0.1 cc. each and 5 with 0.2 cc. each of the water. In place of the fermentation tubes glucose agar may be used. In this case 1 fermentation tube of glucose bouillon should be inoculated with 3 cc. of the water to determine the quantity of gas produced, if there is any. If a large fermentation tube is used, add 5 cc. of the water. From the gas produced in these tubes determine approximately the number of the gas-producing bacteria.

Careful and full notes should be taken on this examination. The preliminary methods for making a bacteriologic

examination have already been given, and this is largely in the nature of an investigation by each student. It is not expected that the special methods other than those used in the laboratory for pathogenic bacteria will be tried.

Examine the milk tubes of the preceding exercise and the cultures made from them.

177. Collecting water. If the water is collected from a spigot or pump, allow it to flow for 2 or 3 minutes first, and then collect the desired quantity (100–200 cc.) in a sterile bottle and cork tightly; if near at hand, absorbent cotton plugs may be used.

If from a stream or river, withdraw the stopper and immerse the sterile bottle, mouth downward, to the depth desired and allow it to fill. There are several mechanical devices for collecting water from considerable depths from the surface.

EXERCISE LVI

THE QUALITATIVE EXAMINATION OF WATER

178. The qualitative examination of water consists in determining the species of bacteria present. From a sanitary standpoint it consists in finding, if present, those species which may be the cause of disease among people or animals consuming it. The pathogenic bacteria which may be in the water will depend upon the conditions ; but usually in this country water is examined for typhoid and hog-cholera bacilli (*B. coli communis* and *Ps. pyocyaneus*).

In India the spirillum of Asiatic cholera may be found in the water. Occasionally anthrax may be suspected. It should be stated that *Ps. fluorescens liquefaciens*, pseudo-typhoid, and the transitional forms of the colon group are to be carefully differentiated from *Ps. pyocyaneus* and *B. typhosus*. Owing to imperfect descriptions many of the common soil and water bacteria cannot be readily identified. The genera are all that is expected here.

REFERENCES. Frankland, Micro-organisms in Water. Fuller, Report Am. Public Health Asso., 1899, p. 580. See recent editions of text-books and reports of the Laboratory Section of the Am. Public Health Association since 1900.

179. Work for this exercise. Examine the cultures made in Exercise LV, count the colonies on the plates, and estimate from them the number of bacteria in a cubic centimeter of the water ; that is, if there are 40 colonies on the plate containing 0.1 cc. of water, there are 400 bacteria in 1 cc. of it.

From the cultures in the grape-sugar media estimate the number of gas-producing bacteria present.

Describe the appearance of the different colonies and indicate the approximate number of each kind.

Keep the plate cultures until the following exercise and reëxamine and count the colonies.

Determine the obviously different genera of bacteria by making a microscopic examination of the different colonies.

180. Estimating the number of gas-producing bacteria in water. If there is gas in all of the 10 fermentation tubes inoculated with 0.1 cc. each, it would show that there were 10 or more of these bacteria in each cubic centimeter. If 3 of the 5 tubes inoculated with 0.2 cc. each contained gas, it would indicate that there were at least 3 gas-producing bacteria in each cubic centimeter. The preliminary results must be verified by repeated examinations.

EXERCISE LVII

EXAMINATION OF CERTAIN BACTERIA NOT STUDIED
IN THE LABORATORY

181. This exercise will be devoted to a study of preparations of important bacteria, fungi, and pathogenic protozoa not cultivated in the laboratory. Unfortunately the number necessarily omitted is large. This demonstration, however, will aid in fixing in the mind an idea of the morphology of these forms which may be of some assistance. Certain of the pathogenic fungi and protozoa, such as the ray fungus of actinomycosis and the protozoa of Texas fever in cattle and malaria in man will also be demonstrated. These will be studied more thoroughly in the course in pathology.

182. Work for this exercise. Examine and make drawings of the bacteria, fungi, and protozoa demonstrated in the preparations furnished.

Complete and hand in all notes on laboratory work.

EXERCISE LVIII

BACTERIOLOGICAL DIAGNOSIS

183. This and the following exercises of this course will be devoted to the application of the methods already studied to practical diagnostic work, or to the making of some examination or examinations, or to carrying out some little investigation that seems best suited to the needs of the student. Just what these will be must be decided by the instructor at the time. We have found very helpful the diagnosis of tuberculosis, diphtheria, anthrax, pyogenic bacteria, and others from mixed cultures or animal tissues. If the student is to continue work in bacteriology, a study of the varieties of some group of bacteria or of some bacterial flora may be better. It is important that the student should learn something of the possibilities and limitations of the methods in practical bacteriological work.

184. Work for this and the following exercises. From the material furnished make such examinations, cultures, or other tests as in your opinion are called for to make the determinations required.

Make careful notes on the work and state fully in your report the reasons for the conclusions reached.

At or before the last exercise have all apparatus for individual use inspected by the instructor and returned to the laboratory.

185. Staining actinomyces. This fungus is stained in cover-glass preparations made from actinomycotic tissue, or in sections by any of the basic aniline dyes. Carbol fuchsin is very good. The Gram method gives very excellent results. It is, however, not easy to obtain nicely stained preparations showing both the "clubs" and the mycelial part of the fungus.

186. Staining blood films for malarial parasites. Several methods of staining blood films to demonstrate malarial

parasites are in use, but the following (Nocht-Romanowsky) gives the most uniform, satisfactory results.

Preparation of stain. 1. To one ounce of polychrome methylene blue (Grübler) add a 3% solution of acetic acid (U.S.P., 33%) drop by drop until it no longer turns red litmus paper blue above the zone coming into immediate contact with the dye. It usually requires about five drops.

2. Make a saturated (1%) watery solution of methylene blue, preferably Ehrlich's (Grübler) or Koch's, dissolving the dye by gentle heat. This solution improves with age, and should be at least one week old.

3. Make a 1% watery solution of Grübler's watery eosin.

The mixture is prepared as follows :

To 10 cc. of water add 4 drops of the eosin solution, 6 drops of neutralized polychrome blue, and 2 drops of 1% methylene blue, mixing well.

Preparation of films for staining malaria organisms in the blood. Clean the finger or ear lobe with alcohol, and prick with a sterile surgical needle or lance so as actually to incise the capillaries. The blood should not be squeezed out, but should flow freely. Wipe away the first two or three drops. Apply the edge of one end of a glass slide to a small drop of blood and place this edge on the surface of another slide resting on a firm surface. As soon as the drop of blood has spread along the line of contact, holding the slide at an angle of about 30°, draw it gently along the surface of the receiving slide, spreading the blood in a thin film. Allow the films to dry in the air before fixing.

Fixing the blood films. 1. By heat. (a) *Open flame.* Pass the slide, specimen side up, slowly through the flame of a Bunsen burner until it is decidedly too hot for the hand to bear. At this temperature, which probably varies from 110° to 150° C., fixation is complete in from 1 to 2 minutes. Over-heated slides can usually be seen to change color in the flame, after which the red cells stain yellowish with eosin. A little

practice will enable one to tell when fixation is complete without overheating. (b) *Ovens*. Slides may be placed in an oven provided with a thermometer and exposed to a temperature of from 110° to 150° C. from 5 to 10 minutes.

2. By alcohol. Fix in from 95% to 97% alcohol from 10 to 30 minutes. If left too long in alcohol they do not stain so well. For staining malarial parasites, fixation by alcohol is preferable.

Method of using the stain. Put the stain in a Petri dish, place in it two or three toothpicks, matches with heads removed, or pieces of small glass rod to support the slides, and place them, specimen side down, in the stain upon this support. This allows any precipitate to settle away from rather than upon the slides. Allow the stain to act one or two hours. They will not overstain in twenty-four hours. Wash in water and when dry they are ready to examine without a cover glass. Immersion oil can be applied directly to the films without injury.

APPENDIX

I

REACTION OF CULTURE MEDIA

THE importance of the reaction of media as a controlling factor in the development of biological characters is of so much importance that the methods recommended by the committee of bacteriologists appointed in 1895 to the American Public Health Association in 1897 are appended to aid those who may not have the transactions of that association at hand.

“The first thing to obtain is a standard ‘indicator’ which will give uniform results. These requirements are best fulfilled by phenolphthalein.

This indicator was first suggested by Schultze in combination with the titration method for obtaining the desired reaction for culture media (Cent. für Bakt. und Parasit., Bd. X., 1891, S. 53), but its general adoption seems to have been retarded largely by Dahmen (Cent. für Bakt. und Parasit., Bd. XII., 1892, S. 620), who claimed that its use was not feasible, owing to complications which might arise from the presence of carbonates and ammonium salts in the solution to be tested. These objections to the use of phenolphthalein do exist, but may be readily overcome.

The amount of free and combined ammonia present in culture media at the time the reaction is determined, has been found not to exceed .003%, which is less than one-tenth the amount which interferes with the accuracy of this indicator; while the production of carbon dioxide is obviated to a very great degree by neutralizing with sodium hydroxid instead of with sodium carbonate, and any of this gas which may be absorbed from the atmosphere is practically all driven off by heat during the preparation of the media.

The great advantage in the use of phenolphthalein over other indicators lies in the fact that it takes into account the reaction of

weak organic acids and of organic compounds which have an amphoteric reaction, but in which the acid character predominates. Turmeric possesses the same properties, but the change in color from a yellow to brown is less satisfactory than the development of purple red color, and furthermore turmeric paper changes color rather slowly, while with phenolphthalein the color appears almost instantly.

Another advantage to be gained from the use of this later indicator is its behavior toward the phosphates. Petri and Maassen (*Arbeiten aus dem K. Gesundheitsamte*, Bd. VIII., 1893, S. 311) and Timpe (*Cent. für Bakt. und Parasit.*, Bd. XIV., 1893, S. 845; Bd. XV., 1894, S. 394-664; Bd. XVII., 1893, S. 416) have shown that the amphoteric reaction of media is associated with the presence of phosphates, and that there are present in peptone and gelatin proteid bodies which possess both an acid and a basic nature, but in which the acid character predominates. These observers agree that to determine accurately the reaction of such amphoteric compounds phenolphthalein, or turmeric paper, should be used as an indicator.

It is known that at the neutral point of phenolphthalein any free phosphoric acid present enters into combination, and the monobasic and tribasic salts of this acid are changed to the dibasic form (Na_2HPO_4). Now disodium hydrogen phosphate reacts alkaline to litmus, lacmoid, rosolic acid, and methyl-orange, but neutral to phenolphthalein and turmeric.

Studies made at the Lawrence Experiment Station show that this acid salt may be added to culture media in amounts greatly exceeding those naturally present in the media without producing any apparent influence upon bacterial development.

From these facts it seems clear that the use of any of the above-mentioned indicators, other than phenolphthalein and turmeric, in the presence of this dibasic phosphate, prevents the addition of a sufficient amount of free alkali to effect neutralization, and as the amount of phosphates in media varies considerably, the reaction passes beyond accurate control when litmus and other substances of its class are used as indicators.

Datum point to which all degrees of reaction shall be referred:

From the available evidence it seems advisable to adopt the phenolphthalein neutral point as the fixed point to which all degrees of reaction shall be referred.

The question of the proper reaction of media for the cultivation of bacteria, and the method of obtaining this reaction, have been discussed in a valuable paper by Mr. George W. Fuller, published in the Journal of the American Public Health Association, Vol. 20, Oct., 1895, p. 321. Some of the main results there given have been mentioned above.

Method of determining the Degree of Reaction of Culture Media. —

For this most important part in the preparation of culture media, burettes, graduated into $\frac{1}{10}$ c.c., and 3 solutions are required.

1. A .5 % solution of commercial phenolphthalein in 50 % alcohol.
2. A $n/20$ solution of sodium hydroxid.
3. A $n/20$ solution of hydric chlorid.

Solutions Nos. 2 and 3 must be accurately made up and must correspond with the normal solutions soon to be referred to. Solutions of sodium hydroxid are prone to deterioration from the absorption of carbon dioxid and the consequent formation of sodium carbonate. To prevent as much as possible this change, it is well to place in the bottle containing the stock solution a small amount of calcium hydroxid, while the air entering the burettes or the supply bottles should be made to pass through a "U" tube containing caustic soda, to extract from it the carbon dioxid.

The medium to be tested, all ingredients being dissolved, is brought to the prescribed volume by the addition of distilled water to replace that lost by boiling, and after being thoroughly stirred, 5 c.c. are transferred to a 6-inch porcelain evaporating dish; to this 45 c.c. of distilled water are added, and the 50 c.c. of fluid are boiled for 3 minutes over a flame. One c.c. of the solution of phenolphthalein (No. 1) is then added, and by titration with the required reagent (No. 2 or 3) the reaction is determined. In the majority of instances the reaction will be found to be so that the $n/20$ sodium hydroxid is the reagent most frequently required. This determination should be made not less than three times, and the average of the results obtained taken as the degree of reaction.

One of the most difficult things to determine in this process is exactly when the neutral point is reached, as shown by the color developed, and to be able in every instance to obtain the same shade of color. To aid in this regard, it may here be remarked that in bright daylight the first change that can be seen on the

addition of alkali is a very faint darkening of the fluid, which on the addition of more alkali becomes a more evident color, and develops into what may be described as an Italian pink. A still further addition of alkali suddenly develops a clear and bright pink color, and this is the reaction always to be obtained.

All titrations should be made quickly and in hot solutions, to avoid complications arising from the presence of carbon dioxide.

When this manipulation is carried out uniformly, as here suggested, and the end point having the same intensity of color is always reached, very satisfactory and closely-agreeing results may be obtained.

Neutralization of Media. — The next step in the process is to add to the bulk of the medium the calculated amount of reagent, either alkali or acid, as may be determined. For the purpose of neutralization a normal solution of sodium hydroxid or of hydric chlorid is used, and after being thoroughly stirred the fluid thus neutralized is again tested in the same manner as at first to insure the proper reaction of the medium being attained. When neutralization is to be effected by the addition of alkali, it not infrequently happens that after the calculated amount of normal solution of sodium hydroxid has been added the second test by titration will show that the medium is still acid to phenolphthalein, to the extent sometimes of from 0.5 to 1 %. This discrepancy is perhaps due to side reactions, which are not understood; the reaction of the medium, however, must be brought to the desired point by the further addition of sodium hydroxid, and the titrations and additions of alkali must be repeated until the medium has the desired reaction (*i.e.* 0.0 % — 0.005 %, see below).

After the prescribed period of heating it is frequently found that the medium is again slightly acid, usually about 0.5 %. Without correcting this the fluid is to be filtered and the calculated amount of acid or alkali is to be added to change the reaction to the one desired.

A still further change in reaction is not infrequently to be observed after sterilization, the degree of acidity varying apparently with the composition of the media and the degree and continuance of the heat.

Manner of expressing the Degree of Reaction of Culture Media. — Since at the time the reaction is first determined culture media

are more often acid than alkaline, it is proposed that acid media be designated by the plus sign and alkaline media by the minus sign, and that the degree of acidity or alkalinity be noted in parts per hundred; thus a medium marked +1.5 would indicate that the medium was acid and that 1.5 % of $N/1$ sodium hydroxid is required to make it neutral to phenolphthalein, while -1.5 would indicate that the medium was alkaline and that 1.5 % of $N/1$ acid must be added to make it neutral to the indicator.

Limits of accuracy of the proposed method for the control of the reaction of media :

The available data are as yet insufficient to warrant any conclusions upon this point. The limits of accuracy seem to vary with the ingredients employed in preparing nutrient media, different samples of meat infusion, pepton, and gelatin appearing to react differently with the acids and alkalis and in a way which is not understood.

This method, nevertheless, when carefully carried out, and when the media before titration are thoroughly mixed and are of the prescribed volume, give fairly uniform results.

Standard reaction of media (provisional) :

Experience seems to vary somewhat as to the optimum degree of reaction which shall be uniformly adopted in the preparation of standard culture media. To what extent this is due to variation in natural conditions as compared with variations of laboratory procedure, it seems impossible to state. Somewhat different degrees of reaction for optimum growth are required, not only in or upon the media of different composition and by bacteria of different species, but also by bacteria of the same species when in different stages of vitality.

The bulk of available evidence from both Europe and America points to a reaction of +1.5 as the optimum degree of reaction for bacterial development in inoculated culture media; and while this experience is at variance with that in several of our own laboratories, it has been deemed wise to adopt +1.5 as the provisional standard reaction of media, but with the recommendation that the optimum growth reaction be always recorded in species descriptions."

II

THE OCULAR MICROMETER AND MICROMETRY¹

Ocular Micrometer, Eye-piece Micrometer. — This, as the name implies, is a micrometer to be used with the ocular. It is a micrometer on glass, and the lines are sufficiently coarse to be clearly seen by the ocular. The lines should be equidistant and about $\frac{1}{10}$ or $\frac{1}{20}$ mm. apart, and every fifth line should be longer and heavier to facilitate counting. If the micrometer is ruled in squares (net micrometer) it will be very convenient for many purposes.

The ocular micrometer is placed in the ocular, no matter what the form of the ocular (*i.e.* whether positive or negative), at the level at which the real image is formed by the objective, and the image appears to be immediately upon or under the ocular micrometer, and hence the number of spaces on the ocular micrometer required to measure the real image may be read off directly. This is measuring the size of the real image, however, and the actual size of the object can only be determined by determining the ratio between the size of the real image and the object. In other words, it is necessary to get the valuation of the ocular micrometer in terms of a stage micrometer.



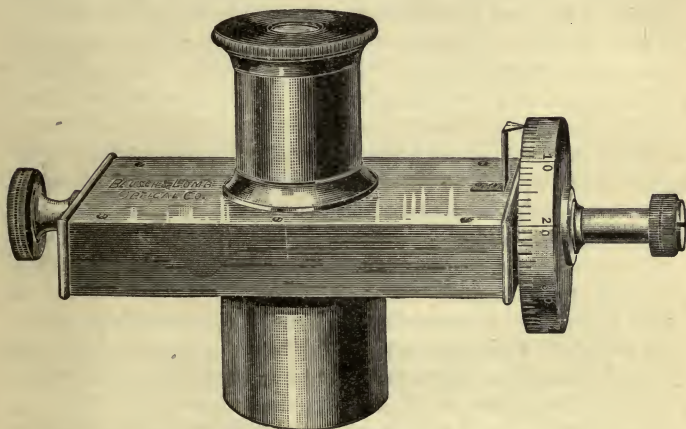
Field of large filar micrometer showing cross hairs and recording comb.

Valuation of the Ocular Micrometer. — This is the value of the divisions of the ocular micrometer for the purpose of micrometry, and is entirely relative, depending upon the magnification of the real image formed by the objective; consequently it changes with every change in the magnification of the real image, and must be specially determined for every optical combination (*i.e.* objective and ocular) and for every change in the length of the tube of the microscope, that is, it is necessary to determine the ocular micrometer valuation for every condition modifying the real image of the microscope (152).

¹These paragraphs are from Professor S. H. Gage's work on the microscope, published here by his consent. The references to sections are to the seventh edition of *The Microscope*.

Any Huygenian ocular may, however, be used as a micrometer ocular by placing the ocular micrometer at the level of the ocular diaphragm, where the real image is formed. If there is a slit in the side of the ocular, and the ocular micrometer is mounted in some way, it may be introduced through the opening in the side. When no side opening exists, the mounting of the eye-lens may be unscrewed and the ocular micrometer, if on a cover-glass, can be laid on the upper side of the ocular diaphragm.

Obtaining the Valuation of the Filar Micrometer.—This micrometer (Figs. 98–99) consists of a Ramsden's ocular and cross lines.



Filar Micrometer.

As seen in Fig. 98 there are three lines. The horizontal and one vertical line are fixed. One vertical line may be moved by the screw back and forth across the field.

For obtaining the valuation of this ocular micrometer an accurate stage micrometer must be used. Carefully focus the $\frac{1}{100}$ mm. spaces. The lines of the ocular micrometer should also be sharp. If they are not, focus them by moving the top of the ocular up or down (164). Make the vertical lines of the filar micrometer parallel with the lines of the stage micrometer. Take the precautions regarding the width of the stage micrometer lines given in 167.

Note the position of the graduated wheel and of the teeth of the recording comb, and then rotate the wheel until the movable lines traverse one space on the stage micrometer. Each tooth of the recording comb indicates a total revolution of the wheel, and by noting the number of teeth required and the graduations on the wheel, the revolutions and parts of revolution required to measure the $\frac{1}{100}$ mm. of the stage micrometer can be easily noted. Measure in like manner four or five spaces and get the average. Suppose this average is $1\frac{1}{4}$ revolutions, or 125 graduations, on the wheel, to measure the $\frac{1}{100}$ mm., or 10μ (157), then one of the graduations on the wheel would measure 10μ divided by $125 = .08\mu$. In using this valuation for actual measurement, the tube of the microscope and the objective must be exactly as when obtaining the valuation (165).

Example of Measurement. — Supposing one used the red blood corpuscles of a dog, or monkey, etc., every condition being as when the valuation was determined, one notes very accurately how many of the graduations on the wheel are required to make the movable lines traverse the object from edge to edge. Suppose it requires 94 of the graduations to measure the diameter, the actual size of the corpuscle would be $94 \times .08\mu = 7.52\mu$.

The advantage of the filar micrometer is that the valuation of one graduation being so small, even the smallest object to be measured would require several graduations to measure it. In ocular micrometers with fixed lines small objects like bacteria might not fill even one space; therefore estimations, not measurements, must be made. For large objects, like most of the tissue elements, the ocular micrometers with fixed lines answer very well, for the part which must be estimated is relatively small, and the chance of error is correspondingly small.

Obtaining the Ocular Micrometer Valuation for an Ocular Micrometer with Fixed Lines (Figs. 33, 34, p. 25). — Use the stage micrometer as object. Light the field well and look into the microscope. The lines of the ocular micrometer should be very sharply defined. If they are not, raise or lower the eye-lens to make them so, that is, focus as with the simple magnifier.

When the lines of the ocular micrometer are distinct, focus the microscope (45, 46, 56) for the stage micrometer. The image of the stage micrometer will appear to be directly under or upon the ocular micrometer.

Make the lines of the two micrometers parallel by rotating the ocular or changing the position of the stage micrometer, or both if necessary, and then make any two lines of the stage micrometer coincide with any two on the ocular micrometer. To do this it may be necessary to pull out the draw tube a greater or less distance. See how many spaces are included on each of the micrometers.

Divide the value of the included space or spaces on the stage micrometer by the number of divisions on the ocular micrometer required to include them, and the quotient so obtained will give the valuation of the ocular micrometer in fractions of the unit of measure of the stage micrometer. For example, suppose the millimetre is taken as the unit for the stage micrometer, and this unit is divided into spaces of $\frac{1}{10}$ and $\frac{1}{100}$ mm. If now, with a given optical combination and tube length, it requires 10 spaces on the ocular micrometer to include the real image of $\frac{1}{10}$ mm. on the stage micrometer, obviously 1 space on the ocular micrometer would include only one-tenth as much, or $\frac{1}{10}$ mm. $10 = \frac{1}{100}$ mm., that is, each space on the ocular micrometer would include $\frac{1}{100}$ of a millimetre on the stage micrometer, or $\frac{1}{10}$ mm. of length of any object under the microscope, the conditions remaining the same. Or, in other words, it would require 100 spaces on the ocular micrometer to include 1 mm. on the stage micrometer, then as before 1 space of the ocular micrometer would have a valuation of $\frac{1}{100}$ mm. for the purposes of micrometry; and the size of any minute object may be determined by multiplying this valuation of 1 space by the number of spaces required to include it. For example, suppose the fly's wing or some part of it covers 8 spaces on the ocular micrometer, it would be known that the real size of the part measured is $\frac{1}{100}$ mm. $\times 8 = \frac{8}{100}$ mm. or 80μ (157).

Varying the Ocular Micrometer Valuation.—Any change in the objective, the ocular, or the tube length of the microscope, that is to say, any change in the size of the real image, produces a corresponding change in the ocular micrometer valuation (152, 161)."

III

ANIMAL INOCULATION FOR PURPOSES OF DIAGNOSIS

It is not always possible by the ordinary culture methods to successfully determine the specific nature of a disease from a small piece of affected organ or tissue of the diseased animal or man. In making a positive diagnosis, therefore, it is often necessary to resort to animal inoculation. This is done by injecting into the animal chosen a small quantity of the tissue or fluid supposed to contain the virus of the specific disease, such as tuberculosis, glanders, rabies, and often of swine plague, hog cholera, anthrax, diphtheria, and others. Animal inoculation is further demandatory in determining the degree of virulence of pathogenic bacteria, the strength of toxins, antitoxins, etc. In other words, the living animal must for the present serve in certain instances as a testing reagent. The fact should be kept in mind that the lesions produced in the experimental animal are not necessarily and in most cases they are not the same as those in the animal (or man) from which the virus was obtained. It is the rule, however, that each virus produces characteristic lesions from which the disease can usually be diagnosed in the smaller animal.

Animals Used. — For simple diagnostic work the guinea pig and rabbit are usually employed, although white and gray mice, dogs, and other animals are sometimes used.

Method. — In preparing the animal for inoculation the hair should be removed over the area of operation by the use of scissors, and the skin washed and disinfected. A solution of corrosive sublimate, 1 to 1000, or a 5% solution of carbolic acid, may be used. The incision should be made with a sharp knife. Liquid material is usually injected with a hypodermic syringe. An anæsthetic should be given whenever the pain inflicted is to be long continued or excessively severe. The place of inoculation should be chosen where a local swelling, infiltration of tissue, or abscess would not interfere with the animal's locomotion.

SPECIFIC DISEASES FOR WHICH ANIMAL INOCULATIONS ARE MOST
COMMONLY RESORTED TO FOR DIAGNOSTIC PURPOSES

Tuberculosis. — Guinea pigs are preferable, although rabbits may be used. With tuberculous tissues either of two methods may be employed. (1) A small piece (about the size of a pea or bean) of the tissue may be inserted under the skin by first making an incision with a sharp scalpel through the skin and superficial fascia and then with a pair of fine forceps insert the bit of tissue well under the skin and close the opening with one or more sutures. (2) The tissue may be crushed in a mortar and thoroughly mixed with a few cubic centimetres of sterile water or bouillon and then injected with a hypodermic syringe. The needle should be of large calibre. If it is suspected milk, it may be injected into the abdominal cavity. If the material is tuberculous and contains living tubercle bacteria, the death of the animal follows in from three weeks to four months. Usually the lymphatic glands of the groin and axilla are enlarged and often caseous. If a guinea pig is used, the liver, spleen, lungs, and kidneys are liable, in the order named, to be affected; if a rabbit, the lungs are often the first of the visceral organs to be attacked. (See pathology for description of tissue changes.)

Glanders. — Male guinea pigs should be used. The material usually consists of the nasal discharge from the suspected glandered horse, or bits of scrapings from the ulcers, or pieces of affected tissue. The method to be followed is precisely the same as with the subcutaneous injection of tuberculous material. In these cases there is liable to be a local swelling and abscess. The first indication of glanders noticed is usually orchitis. The lymphatic glands in the groin are also enlarged. After the orchitis becomes well marked the guinea pig may be chloroformed and examined. Pure cultures of the specific organism can be obtained in most cases from the suppurating focus in the testicle. The spleen is usually enlarged and sprinkled with grayish nodules. Other organs may be involved.

Rabies. — The method usually followed in diagnosing rabies is to inoculate a rabbit, guinea pig, or dog beneath the dura with a bit of the brain or spinal cord of the suspected rabid animal. Other methods are being introduced and the guinea pig is reported by some to respond more promptly, but in my experience the subdural

inoculation of rabbits has been most reliable. The injection through the optic foramen has been tried. The subdural method is, briefly stated, as follows :

The brain of the suspected animal is removed with aseptic precautions as soon as possible after death. A small piece of the brain or spinal cord is placed in a sterile mortar and thoroughly ground with a few cubic centimetres of sterilized water or bouillon. This forms the suspension to be injected. The hands of the operator and all instruments are carefully disinfected. The rabbit is etherized, the hair clipped from the head between the eyes and ears, and the skin thoroughly washed and disinfected. A longitudinal incision is then made, the skin and subcutaneous tissue held back by means of a tenaculum, a crucial incision is made in the periosteum on one side of the median line to avoid hemorrhage from the longitudinal sinus, and the four corners of the periosteum reflected or pushed back. By the aid of a trephine a small button of bone is easily removed, leaving the *dura mater* exposed. With a hypodermic syringe a drop or more of the rabid brain suspension is injected beneath the dura, the periosteum is replaced, the skin carefully sutured and disinfected, and the rabbit returned to its cage. As soon as the influence of the anæsthetic has passed off, the rabbit shows no appearance of discomfort. If the operation is performed in the forenoon, the animal partakes of its evening meal with the usual relish. The inoculation wound heals rapidly and the rabbit exhibits *every appearance of being in perfect health* until the beginning of the specific symptoms, which occur ordinarily in from 15 to 30 days, usually in about 20 days after the inoculation. Occasionally the symptoms appear earlier than 15 days and in some cases the rabbits are not attacked for from 1 to 3 months.

The symptoms following the inoculations have in my experience been quite uniform, the only pronounced difference being in the length of time the rabbits lived after the initial manifestation of the disease. The fact should be clearly stated that rabbits do not ordinarily become furious. In some instances they are somewhat nervous for a day or two preceding the paralysis. There appears to be a marked hyperæsthesia. Usually the first indication of the disease is a partial paralysis of one or both hind limbs. This gradually advances until the rabbits are completely prostrated, the only evidence of life being a slight respiratory move-

ment. The head occupies different positions. In some it is drawn back as in tetanus; in others it is drawn down with the nose near the fore legs; and in still others it is extended as if the animal were sleeping. The period of this complete paralysis varies from a few hours to a few days, but ordinarily it does not exceed 24 hours. Although the animals are unable to move voluntarily, there is usually a reflex action of the limbs until a very short time before death.

During the period of incubation the temperature of the rabbits remains normal. As the time approaches for the first symptoms to appear there has been in the animals tested an elevation of temperature of from 1 to 2 degrees, which continued for a variable length of time, but rarely longer than 2 days. This is followed by a gradual or usually a more rapid drop to the subnormal, which continues to the end.

Swine Plague. — Rabbits are most susceptible. Inoculate subcutaneously with a bit of the pneumonic tissue, either in a solid piece or in a suspension in bouillon hypodermically. In case of virulent swine-plague bacteria, the rabbit will die in from 16 to 36 hours from septicæmia. Pure cultures can be obtained from the blood, spleen, liver, or kidney. Stained cover-glass preparations from these organs show a greater or less number of polar-stained bacteria.

In case of a more attenuated virus the rabbit will live from a few days to several weeks and possibly months. In these cases there are usually marked local cell infiltrations, with inflammation of one or more of the serous membranes and possibly metastatic abscesses.

Hog Cholera. — Rabbits are most desirable. They are inoculated in the same manner as with tuberculosis. With ordinarily virulent bacteria the rabbits will die in from seven to ten days. The lesions are essentially a purulent infiltration of the subcutis at the point of inoculation, an enlarged and very dark colored spleen, and areas of coagulation necrosis in the liver. Pure cultures can be obtained from the blood, liver, or spleen.

Anthrax. — Mice or guinea pigs should be used. They are inoculated in the manner described above. They die of septicæmia usually in from 24 to 72 hours. It is not commonly necessary to resort to animal inoculation with this disease. Occasionally, however, it is a very necessary procedure in making an early diagnosis.

Diphtheria. — Guinea pigs are nearly always used. In certain rare

cases of mixed cultures taken directly from the suspected throat it is desirable to inoculate one or more guinea pigs to determine whether the suspected organism present is a virulent Klebs-Loeffler bacterium. In these cases a suspension of the growth on the serum may be injected. The guinea pig dies usually in from 36 to 80 hours. The lesions produced have been described by Park as follows:

“At the seat of inoculation there is a grayish focus surrounded by an area of congestion; the subcutaneous tissues for some distance around are œdematous; the adjacent lymph nodes are swollen; and the serous cavities, especially the pleural and the pericardial, frequently contain an excess of fluid, usually clear, but at times turbid; the lungs are generally congested. In the organs are found numerous smaller and larger masses of necrotic cells, which are permeated by leucocytes. The heart and voluntary muscle fibres usually show degenerative changes. Occasionally there is fatty degeneration of the liver and kidneys. The number of leucocytes in the blood is increased. From the area surrounding the point of inoculation, virulent bacilli may be obtained, but in the internal organs they are only occasionally found, unless an enormous number of bacilli have been injected. Paralysis, commencing usually in the posterior extremities, and then gradually extending to other portions of the body and causing death by paralysis of the heart or respiratory organs, is also produced in many cases in which the inoculated animals do not succumb to a too rapid intoxication.”

Guinea pigs are used for testing the virulence of pure cultures and the strength of the toxin and antitoxin. For further details, see text-books of bacteriology.

IV

CULTIVATION OF BACTERIUM (BACILLUS) TUBERCULOSIS

The isolation of this organism from tuberculous lesions and getting it to multiply readily on artificial media necessitates a very special and careful procedure. When it becomes accustomed to artificial media its continued cultivation is not difficult. Dr. Theobald Smith, of Harvard University (*Jour. of Exp. Med.*, Vol. III., 1898, p. 451), has the credit of formulating a method by combining details in such a manner that the procuring of cultures is, in most cases, possible. Dog serum is used. The method, as he gives it, is as follows, viz. :

"The dog was bled under chloroform and the blood drawn from a femoral artery, under aseptic conditions, through sterile tubes directly into sterile flasks. The serum was drawn from the clots with sterile pipettes and either distributed at once into tubes or else stored with 0.25 to 0.3% chloroform added. Discontinued sterilization was rendered unnecessary. The temperature required to produce a sufficiently firm and yet not too hard and dry serum is for the dog 75° to 76° C. For horse serum it is from 4° to 5° lower. The serum was set in a thermostat into which a large dish of water was always placed to forestall any abstraction of moisture from the serum. About 3 hours suffice for the coagulation. When serum containing chloroform is to be coagulated, I am in the habit of placing the tubes for an hour or longer in a water bath at 55° to 60° C., or under the receiver of an air pump, to drive off the antiseptic. This procedure dispenses with all sterilization excepting that going on during the coagulation of the serum. It prevents the gradual formation of membranes of salts, which, remaining on the surface during coagulation, form a film unsuited for bacteria. Tubes of coagulated serum should be kept in a cold closed space where the opportunities for evaporation are slight. They should always be kept inclined.

The ordinary cotton-plugged test tubes I do not use, because of the rapid drying out permitted by them, as well as the opportunities for infection with fungi. Instead, a tube is used which has a ground glass cap fitted over it. This cap contracts into a narrow tube

plugged with glass wool. This plug is not disturbed. The tube is cleaned, filled, and inoculated by removing the cap. With sufficient opportunity for the interchange of air little evaporation takes place, and contamination of the culture is of very rare occurrence. In inoculating these tubes, bits of tissue, which include tuberculous foci, especially the most recent, are torn from the organs and transferred to the serum. Very little crushing, if any, is desirable or necessary. I think many failures are due to the often futile attempts to break up firm tubercles. Nor should the bits of tissue be rubbed into the surface, as is sometimes recommended. After a stay of several weeks in the thermostat, I usually remove the tubes and stir about the bits of tissue. This frequently is the occasion for a prompt appearance of growth within a week, as it seems to put certain still microscopic colonies in or around the tissue into better condition for further development. The thermostat should be fairly constant, as urged by Koch in his classic monograph, but I look upon moisture as more important. If possible, a thermostat should be used which is opened only occasionally. Into this a large dish of water is placed, which keeps the space saturated. Ventilation should be restricted to a minimum. As a consequence, moulds grow luxuriantly and even the gummed labels must be replaced by pieces of stiff manila paper fastened to the tube with a rubber band. By keeping the tubes inclined, no undue amount of condensation water can collect in the bottom, and the upper portion of the serum remains moist. The only precaution to be applied to prevent infection with moulds is to thoroughly flame the joint between tube and cap as well as the plugged end, before opening the tube. When test tubes are employed it is well to dip the lower end of the plug into sterile molten paraffin and to cover the tube with a sterilized paper cap. The white bottle caps of the druggist are very serviceable."

Unless the tuberculous material is perfectly fresh (uncontaminated), and in the early stages of the disease, it is safer to inoculate a guinea pig, and after the lesions begin to develop to chloroform it and make the cultures from the recently affected liver or spleen.

JEFFERS PLATE

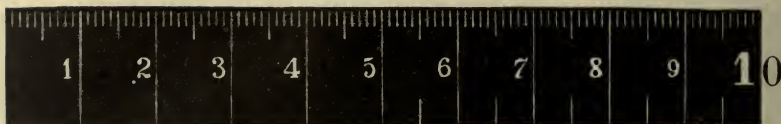
FOR COUNTING COLONIES OF BACTERIA IN PETRI DISHES.

The area of each division is one square centimeter.



V

THE METRIC SYSTEM.



10 CENTIMETER RULE.

The upper edge is in millimeters, the lower in centimeter and half centimeters.

UNITS.

The most commonly used divisions and multiples.

THE METER FOR LENGTH . . .	{	Centimeter (cm.), 1/100th meter; millimeter (mm.), 1/1000th meter; micron (μ), 1/1000th millimeter; the micron is the unit in Micrometry.
		Kilometer, 1000 meters; used in measuring roads and other long distances.
THE GRAM FOR WEIGHT . . .	{	Milligram (mg.), 1/1000th gram.
		Kilogram, 1000 grams; used for ordinary masses.
THE LITER FOR CAPACITY . .	{	Cubic centimeter (cc.), 1/1000th liter. This is more common than the correct form, milliliter.

Divisions of the Units are indicated by the Latin prefixes: deci, 1/10th; centi, 1/100th; milli, 1/1000th.

Multiples are designated by Greek prefixes: deka, 10 times; hecto, 100 times; kilo, 1000 times; myria, 10,000 times.

Table of Metric and English Measures.

Meters = 100 centimeters, 1000 millimeters, 1,000,000 μ , 39.3704 inches.
 Millimeter (mm.) = 1000 microns, 1/10th millimeter, 1/1000th meter, 1/25th inch, approximately.

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Gram = 15.432 grains.

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Ounce avoirdupois = (437 1/2 grains) = 28.349 grams.

Ounce troy or apothecary's = (480 grains) = 31.103 grams.

Temperature.

To change Centigrade to Fahrenheit: $(C. \times 9/5) + 32 = F.$ For example, to find the equivalent of 10° Centigrade, $C. = 10^{\circ}$ $(10^{\circ} \times 9/5) + 32 = 50^{\circ} F.$

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(From "The Microscope," by Prof. S. H. Gage, used here with his permission.)

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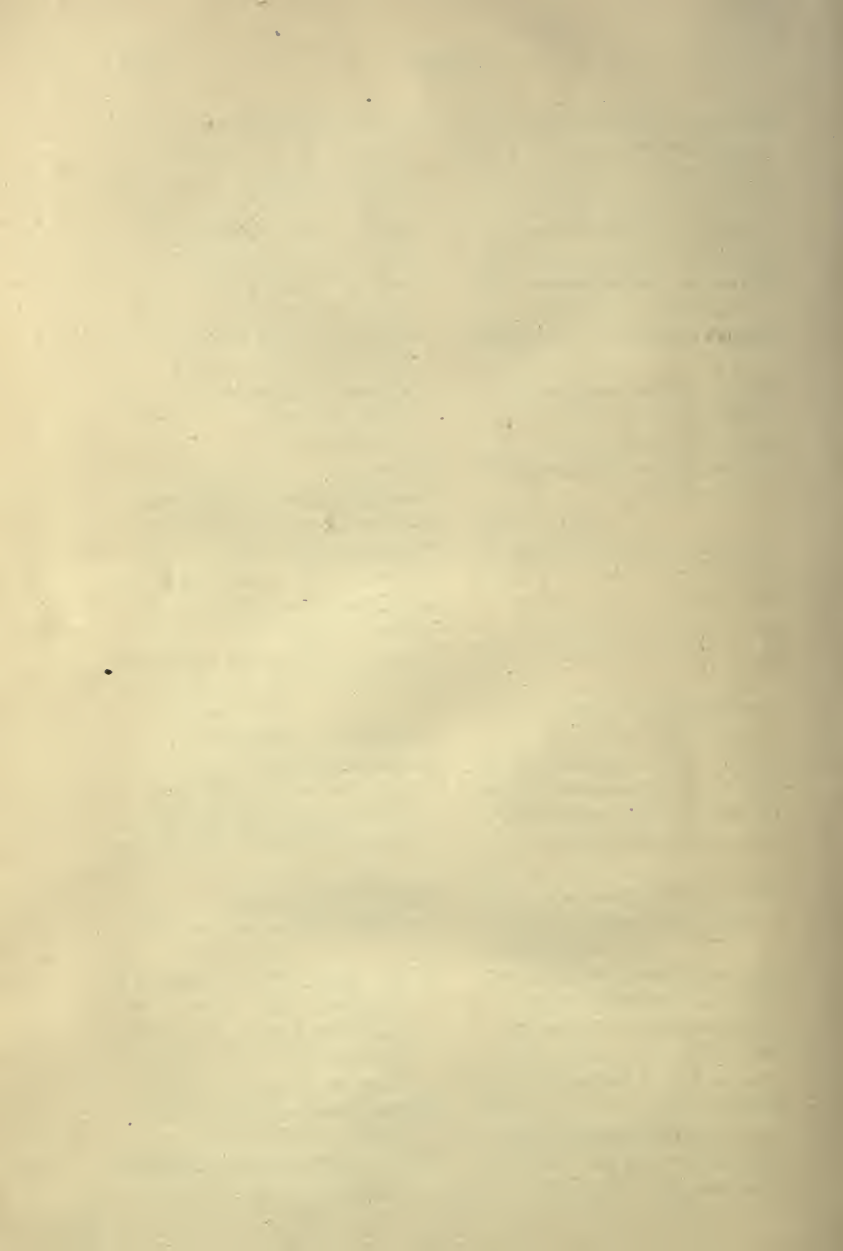
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